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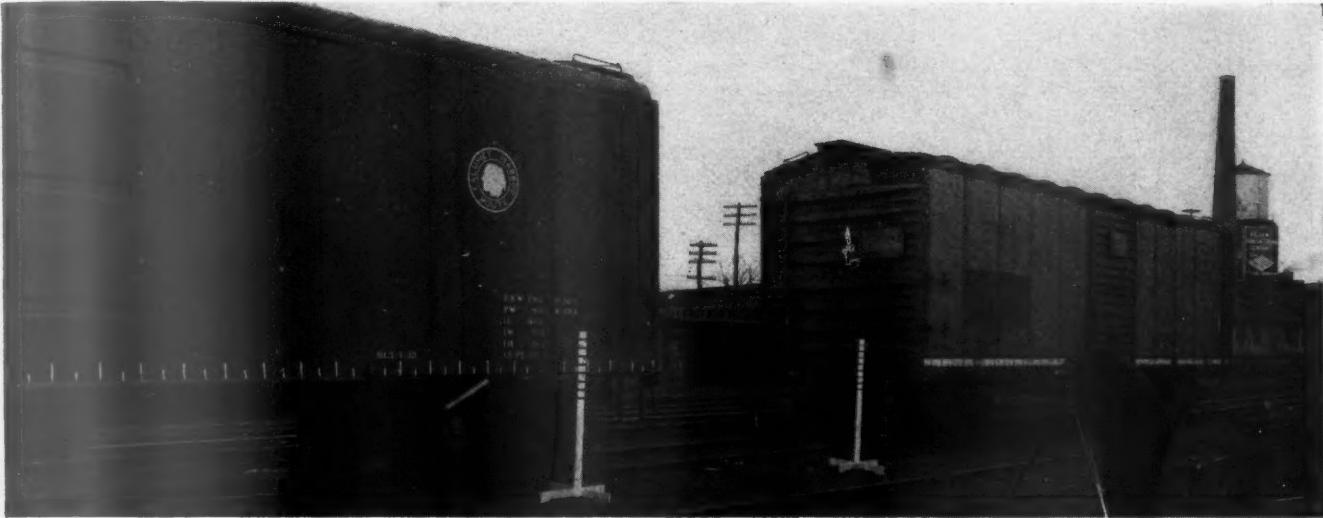
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Impact test, with A.A.R. standard box car about to strike Pullman-Standard all-welded alloy-steel car P.L.M. 500—Car speed recorded by movie camera

DYNAMIC STRESSES IN

Freight-Car Design

IT HAS been the feeling of the Pullman-Standard Car Manufacturing Company for a considerable period that the ratio of car light weight to revenue lading capacity is an important economic transportation factor. Just what the savings are or will be a year per car, due to saving a pound in tare weight, we cannot predict in dollars and cents, except in specific cases. That there is a saving is admitted by all, but we return to the basic query, what does it cost to haul a ton a mile?, and the answer can be given only in specific cases. It is apparent that very small savings in car light weight would not be especially attractive, but if these savings were of some magnitude and could be obtained without sacrifice of car life and strength, and without any considerable increase in cost, the savings would be attractive in reducing operating costs by reducing train-miles for a given volume of traffic.

Formerly, the sizes of stress members in car structures were calculated by formulae, which assured cars of ample strength to meet service requirements, but we didn't know the detailed stresses throughout the structure and the exact ratio of static to live-load stresses at any one point. The above live-load stresses are the ones produced by car body and lading, due to track variation and defects. We had considerable experience in procuring static load stresses by means of extensometers which are calibrated to indicate stresses at any point in pounds

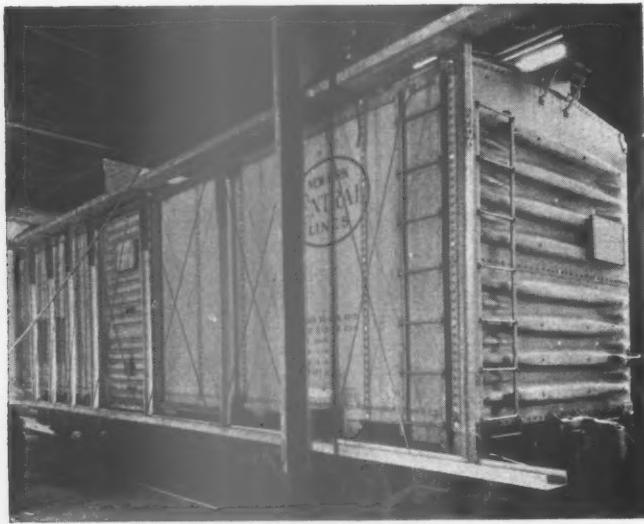
* Research engineer, Pullman-Standard Car Manufacturing Company, Chicago.

By W. H. Mussey*

Abstract of a Western Railway Club paper showing that much of the guesswork can be taken out of car design

per sq. in. But these instruments are of the indicating type and will not truly indicate live load or vertical impact, they merely show static stresses.

By taking stress readings at increments of the static load up to full load, we established a static stress trend line. Using a deflectometer (designed and built by us) under the same conditions at the same positions, we obtain deflections corresponding to the extensometer readings, and these deflections are plotted to establish a static deflection trend. The deflectometers are mounted on a framework supported only at the body bolster position at the sidesill, thus insuring deflections being referred to fixed positions. Two wedge-type blocks are placed one on each rail, one being approximately 18 in. forward of the other. The two wedges are of the same height and are used in increments up to $2\frac{1}{2}$ in. in height at the peak or drop-off point. The car is pulled slowly over these wedges, and, at the top, there is an abrupt drop to the rail. The action approximates passing over

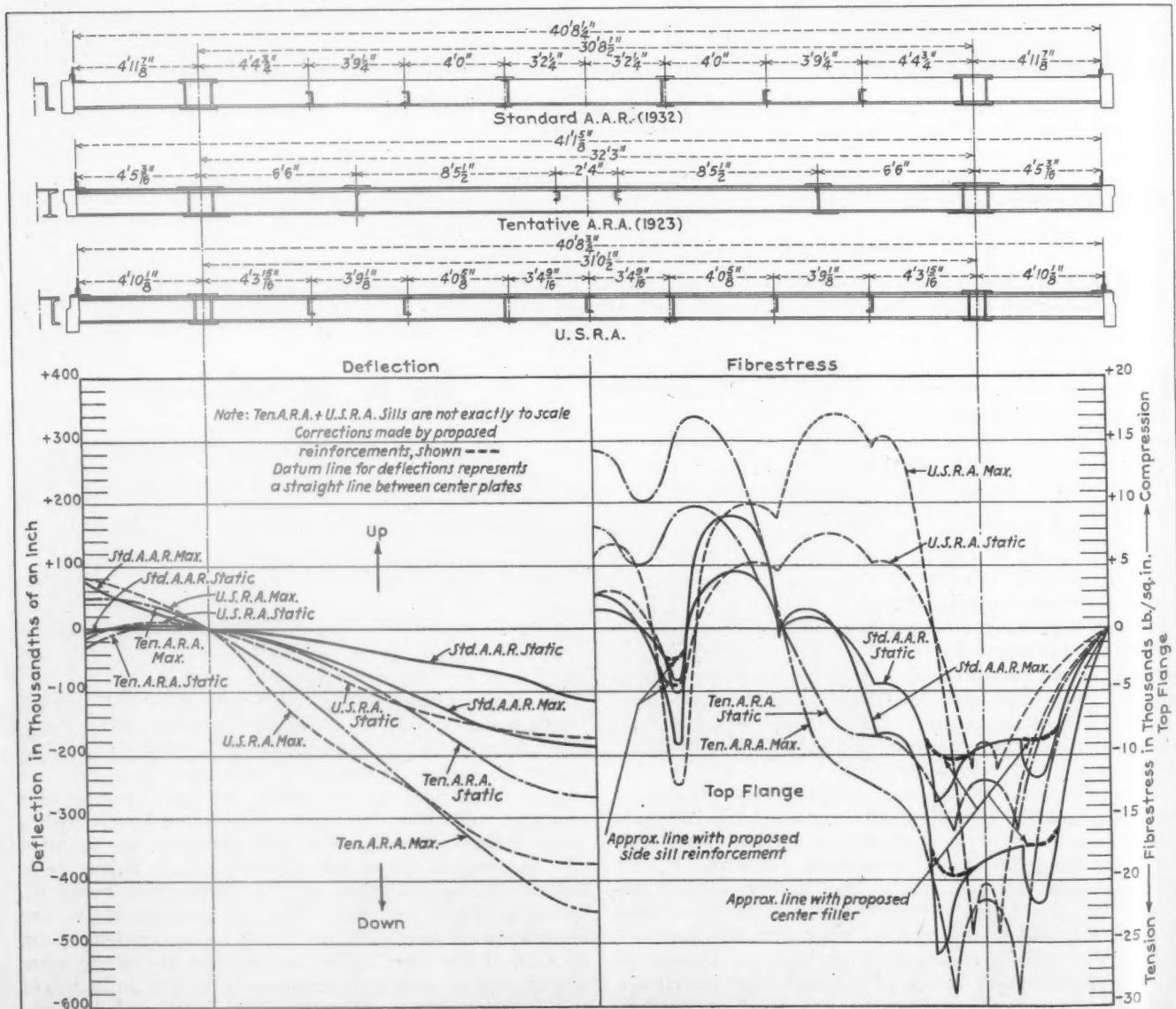


Special frame used in checking the car structure, after impact tests, to detect permanent set in any of its members

rail joints at high speed. The deflections obtained under this test are plotted as an extension of the deflection graph. If there has been no distortion of the structure

and the stresses are within the yield points of the materials, the stresses are proportional to deflections and the stress graph is extended on that basis to cover live-load stresses. It might be said that the frame supporting the deflectometers is subject to some deflection, due to its inertia when dropping off the wedge blocks. These frame deflections are all recorded and correction curves established which are used as deducts to insure proper deflection readings. We established a $2\frac{1}{2}$ -in. wedge height as the maximum necessary for testing purposes by a rather unique method, observing the maximum distortion of framing members in various types of cars. We loaded the cars to journal capacity and increased the height of track wedges to a point that dropping of the car structure from that height at least duplicated the distortion observed.

One of the illustrations shows the deflectometer and extensometer applications on a car ready for testing. The readings recorded by the deflectometer pencil are approximately eight times the actual deflection. Each small division on the extensometer is approximately 1,000 lb. per sq in. for a material having a modulus of elasticity of 29,400,000, which corresponds to low-carbon normal steel. These instruments are always calibrated previous to making tests. Data are developed and curves



Typical comparative deflection and stress curves showing superiority of the A. A. R. standard center sill—Peak stresses still further reduced in car P. L. M. 500 design

drawn for the maximum static and live-load stresses and deflections.

A study of deflections and stresses in the P. L. M. welded Cor-Ten steel box car, designed and built in 1935 by the Pullman-Standard Car Manufacturing Company, indicates, first, the low magnitude of the stresses; second, lack of concentrated or peak stress and uniform smoothness of deflection and stress curves; third, the relatively small increase of live over static load deflections and stresses.

In comparing the A. A. R. standard box car and the light-weight welded box car, P. L. M. No. 500, the stress curves of the latter car are reduced in proportion to the yield strength of the two kinds of steel used E. I. 3 to 5. It is apparent from the foregoing that the investigation of stresses and deflections of load carrying is of such completeness as to thoroughly develop full data and a comprehensive check for all vertical loading, both static and live load.

Further investigations cover the behavior of the car structure under car or train impact conditions, the car tested being the struck car, as it is subjected to a considerably greater blow than the striking car.

How Impact Tests Were Made

In the test illustrated, the P. L. M. welded box car No. 500 was the struck car and N. Y. C. car No. 100,000 standard A. A. R. riveted car was the striking car.

Various spots, about 400 in number for each car, were located as measurement points for ascertaining the static deflection or distortion from light car to full capacity load, and again measurements after each series of impacts, and finally observation of structure stabilization or permanent set with load removed at desired intervals after final runs. The spots cover all positions required to give full data for drawing curves for all essential parts of the car body.

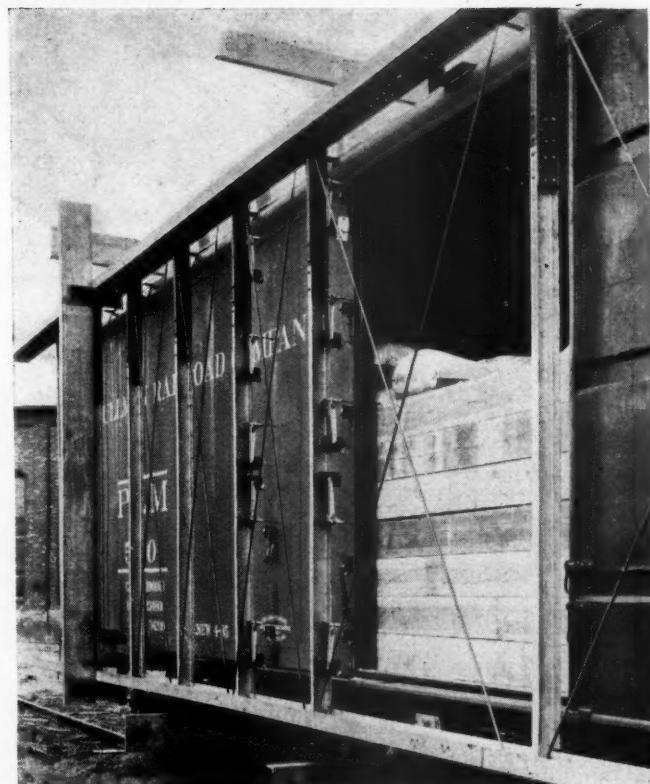
One of the illustrations shows bags loaded in a car, each bag weighing 100 lb. and being filled with a mixture of sand and sawdust, so that with cars loaded to load-carrying capacity, the height of the load in the car is sufficient to give a severe operating condition. The same method of loading was followed out in connection with extensometer and deflectometer tests for vertical load action.

Two sets of tests were made: first, a fully loaded moving car striking a single fully loaded test car at rest at speed increments increasing at the rate of about one mile an hour up to about a 16 m.p.h. speed; second, a fully loaded moving car striking a half loaded test car at rest at the head of a string of five or six empty cars.

The two types of impact tests cover all service conditions. The first described has always proved the more severe. Speeds have been used in some of these tests as high as 18 m.p.h. in connection with impacts between striking car and struck car. The testing procedure follows: Relatively straight, level trackage is selected, of sufficient length to permit the struck car rolling to a stop.

The struck car is placed at a marked spot on the rail, so that the travel to stop can be accurately measured for both striking and struck car.

Coupler knuckles are held open so that movements of the striking and the struck car are independent. Speed at the time of impact is accurately checked for each test run. Coupler or draft-gear movement for each car is taken from the chart. The movement shown on the impact-registering instrument on each car is recorded. Truck springs are checked to ascertain the force acting on these springs for all trucks. The distance each car moved from the point of impact is measured. All de-



Car P.L.M. 500 equipped with extensometers and deflectometers, the latter being supported on a light but rigid metal frame

fects are recorded in detail. On the average, three or four test runs constitute a group, and each group approximates a speed increase of three to four miles per hour.

After each group of runs, the cars are minutely examined for defects and any conditions brought about by the group of tests. They are then placed in the measuring frame and the complete set of measurements taken. These are recorded and afterward drawn up in chart form for each group of tests. A contour sketch is made showing shifting and lading.

If deemed advisable, the load is removed and measurements made, as a check against the original condition. Otherwise, the load is leveled off to the original condition and the next group of test runs is carried out.

The impact test might almost be called a destructive test. The speeds obtained are far above those which occur in service. The shifting of lading and its wedging action is cumulative, beyond a point of which we have any knowledge as occurring in operation. Maybe the test is too severe when compared to everyday service. Anyone can surmise the effect on car lading subjected to these test conditions. However, the data obtained is invaluable as a check on the structure and as information for the car designer and builder.

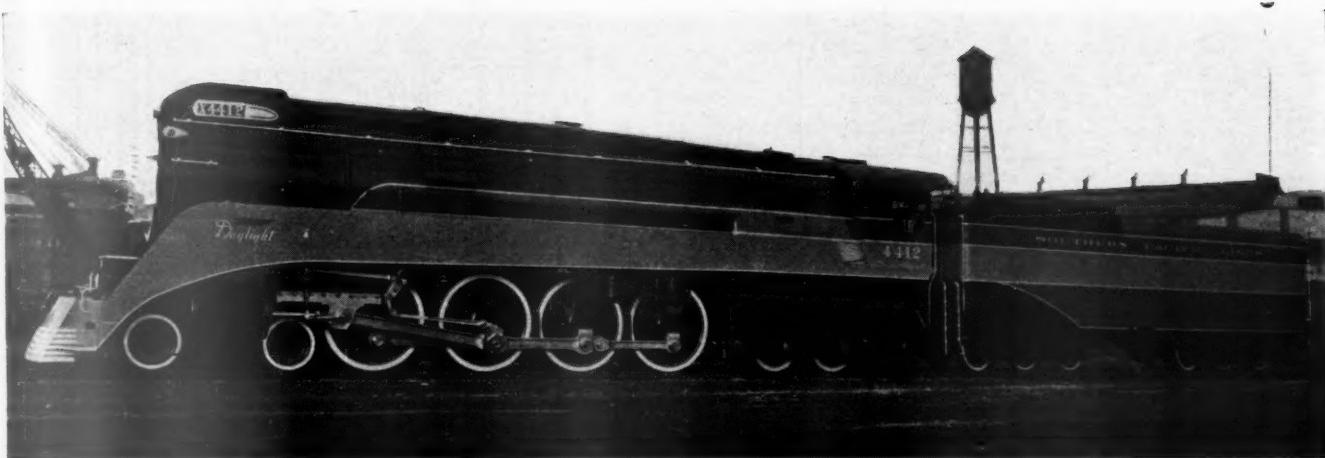
"Where Do We Go From Here?"

Naturally, the question is, where do you go from here? Car structure essentials are thus brought to the attention of the car designer and builder. He knows which stress members of the structure may be reduced in section or, in rare cases, which may be increased. He knows the allowance that must be made for live or dynamic load over static load for each member, as the ratio is not constant for all parts of the car.

With the usual materials of car construction he knows the value of a pound at any particular point in the structure and how light a structure can be safely built. With
(Continued on page 122)



The streamlining and decoration of the front end of the Southern Pacific locomotives is simple and effective. The smokebox front is aluminum and the pilot orange with aluminum bands



Southern Pacific 4-8-4 type passenger locomotive streamlined and finished to conform to the train

Streamline

Steam Passenger Locomotives

THE Lima Locomotive Works, Inc., has delivered six streamline passenger locomotives of the 4-8-4 type to the Southern Pacific for use on the new Daylight train service between Los Angeles and San Francisco to be inaugurated during the coming spring. The locomotives develop 74,710 lb. tractive force, including the trailer booster. The weight on drivers is 266,500 lb., the cylinders are 27 in. by 30 in., the driving wheels 73½ in. in diameter, and the boiler pressure 250 lb. per sq. in.

These locomotives have been streamlined by enclosing the sandbox, dome and other equipment mounted on the top of the boiler within a smooth casing, and by applying deep aprons below the outside edges of the running boards, which join the metal-covered pilot in long sweeping curves. The headlight is enclosed within a casing which is faired into the smokebox door and through the sides of which are openings for the illuminated engine numbers.

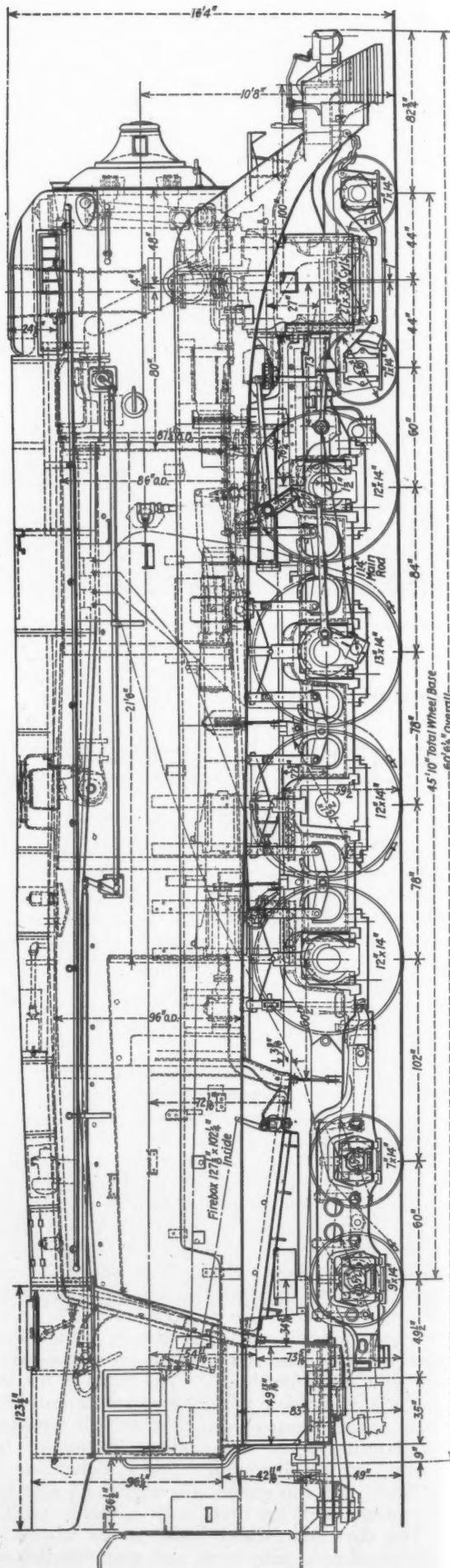
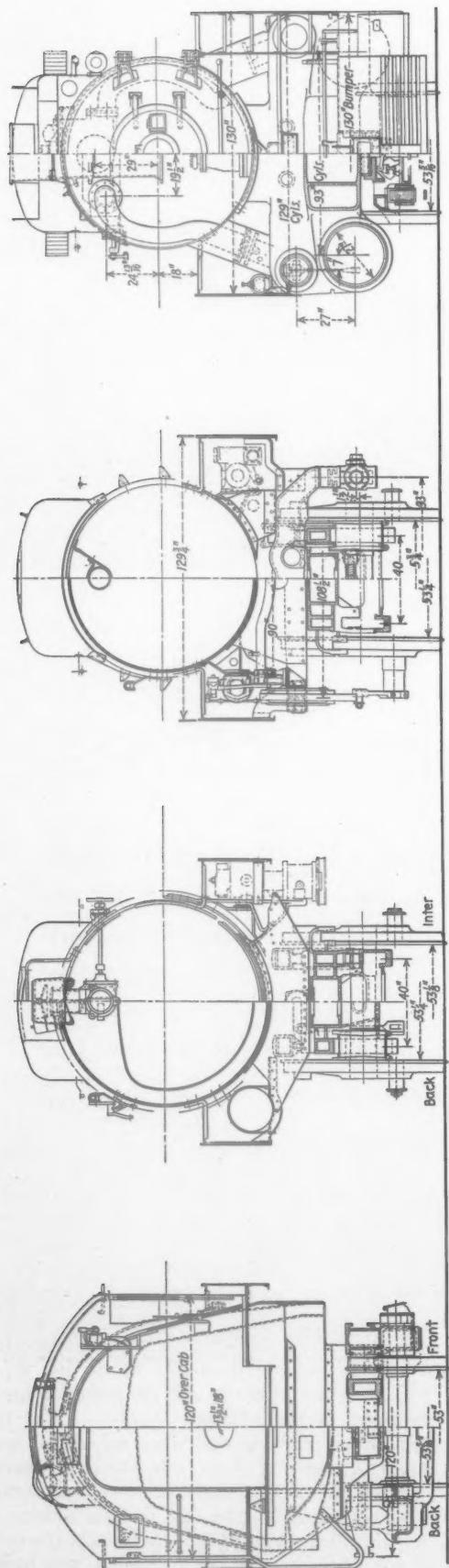
A striking color effect has also been achieved by the extensive use of red and orange on the sides of the locomotive and tender. The smokebox front is painted aluminum and the train-number indicators are aluminum with black stripes. The streamline hood of the pilot is in orange with aluminum bands. The name of the train is lettered in aluminum on the orange of the apron below the running board on each side. The emblem associated with the lettering is in red, outlined in black. The marker lamps are in aluminum. The cylinders are finished in black, and the guides, the main and side rods and the motion work are steel with a highly polished finish. The tires and wheel rims on all wheels are painted in aluminum, with steps and grab handles cad-

Southern Pacific light-weight trains, working over a severe profile on accelerated schedules, call for high traction and fast running. The Lima-built locomotives are designed for this specific service

mium plated. The red on the sides of the boiler above the running board and on the sides of the tender, separated by the band of orange, will match the same color on the sides of the coaches and the yellow panel will line up with the window panel of the coaches.

The Boiler

The boiler has an outside diameter of 86 in. at the first ring. It is designed to carry 250 lb. pressure and is built of carbon steel of basic flange quality. The firebox is equipped for oil burning and the combustion space includes a chamber extending 60 in. into the boiler barrel. Welding is employed at the ends of the longitudinal seams in the barrel courses, and the firebox sheets are seal welded to the mud ring 12 in. each way from the corners. Calking edges of the back firebox are lightly welded to the crown sheet after calking. The staybolts are of Ulster iron with an installation of Flannery tell-tale type flexible bolts at the usual corner breaking zones



Cross-sections and elevation of the Southern Pacific locomotive

and also completely around the combustion chamber. The firebox is equipped with an installation of fusible plugs of the type developed on the Southern Pacific. There are three plugs along the top center line, one between the first and second rows of the crown stays, one between the seventh and eighth, and one between the fifteenth and sixteenth rows. Two laterally spaced plugs are located between the eleventh and twelfth rows.

The boiler is equipped with a type E. superheater with a Tangential steam dryer in the dome. An American multiple front-end throttle is built in the superheater header. The feedwater heater is the Worthington type SSA. The boiler is also equipped with the Signal Foam-Meter.

The foundation for these locomotives is a steel bed

General Dimensions, Weights and Proportions of the Southern Pacific 4-8-4 Type Locomotives

Railroad	Southern Pacific
Builder	Lima Locomotive Works
Type of locomotive	4-8-4
Road class	G-52
Road numbers	7646-7651
Date built	1936
Service	Passenger
Dimensions:	
Height to top of stack, ft. and in.	16-4
Height to center of boiler, ft. and in.	10-8
Width overall, in.	10-11
Cylinder centers, in.	93
Weights in working order, lb.:	
On drivers	266,500
On front truck	77,400
On trailing truck	104,500
Total engine	448,400
Tender	372,880
Wheel bases, ft. and in.:	
Driving	20-0
Rigid	13-0
Engine, total	45-10
Engine and tender, total	94-1/2
Wheels, diameter outside tires, in.:	
Driving	73 1/2
Front truck	36
Trailing truck	45 1/2
Engine:	
Cylinders, number, diameter and stroke, in.	2-27x30
Valve gear, type	Walschaert
Valves, piston type, size, in.	12
Maximum travel, in.	7 1/4
Steam lap, in.	1 3/4
Exhaust clearance, in.	3/16
Lead, in.	3/4
Boiler:	
Type	Conical
Steam pressure, lb. per sq. in.	250
Diameter, first ring, outside, in.	86
Diameter, largest, outside, in.	96
Firebox length, in.	127 1/2
Firebox width, in.	102 1/4
Combustion chamber length, in.	60
Tubes, number and diameter, in.	49-2 1/4
Flues, number and diameter, in.	198-3 1/2
Length over tube sheets, ft. and in.	21-6
Fuel	
Grate area, sq. ft.	90.4
Heating surfaces, sq. ft.:	
Firebox, total	350
Tubes and flues	4,502
Evaporative, total	4,852
Superheating	2,086
Comb. evap. and superheat	6,938
Feedwater heater, type	Worthington
Tender:	
Type	Rectangular
Water capacity, gal.	22,000
Fuel capacity, gal.	6,275
Trucks	6-wheel
Journals, dia. and length, in.	7x14
General data, estimated:	
Rated tractive force, engine, 83 per cent boiler pressure, lb.	62,200
Rated tractive force, booster	12,510
Total rated tractive force	74,710
Weight proportions:	
Weight on drivers + weight engine, per cent.	59.2
Weight on drivers + tractive force	4.28
Weight of engine + comb. heating surface	64.63
Boiler proportions:	
Firebox heat. surface, per cent evap. heat. surface	7.21
Tube-flue heat. surface, per cent comb. heat. surface	64.9
Superheat. surface, per cent evap. heat. surface	30.07
Firebox heat. surface + grate area	3.87
Tube-flue heat. surface + grate area	49.8
Superheat. surface + grate area	23.08
Comb. heat. surface + grate area	76.75
Tractive force, engine + grate area	688.05
Tractive force, engine + comb. heat. surface	8.97
Tractive force, engine x dia. drivers + comb. heat. surface	658.94

casting with which the cylinders are cast integral. The firebox is supported, both front and back, by expansion sheets. These are attached to bolting flanges which extend practically across the entire length of the front and back mud-ring members and are supported from ample bolting flanges on the bed casting both inside and outside of the side-frame parts of the casting.

The engine and trailer trucks are also General Steel Castings design, the former with inside bearings and the latter of the four-wheel Delta type. The trucks are all fitted with oil-packed journal boxes. The driving wheels are cast steel of the Boxpok type. All driving axles, as well as the engine-truck and trailer axles, are of medium carbon steel normalized and drawn.

The cylinders are fitted with two-stage bushings which, like the valve bushings, are of Hunt-Spiller gun iron. The valve bull rings are also of this material and are fitted with Hunt-Spiller duplex sectional packing rings. The pistons are of cast steel, without separate bull rings, and are fitted with the Locomotive Finished Material Company's bronze packing rings. Paxton-Mitchell packing is applied to the valve stems and piston rods.

All rods and motion work are finished with a high polish, free from surface marks, in accordance with the

Partial List of Equipment and Materials on the Southern Pacific 4-8-4 Type Locomotives

Engine bed castings; engine and trailer trucks	General Steel Castings Corp., Eddystone, Pa.
Front drawhead castings	National Malleable & Steel Casting Co., Cleveland, Ohio
Trucks and boxes for tender	Buckeye Steel Castings Co., Columbus, Ohio
Springs	American Locomotive Company, Railway Steel Spring Division, New York
Snubber springs	Cardwell Westinghouse Co., Chicago
Wheels	Edgewater Steel Co., Pittsburgh, Pa.
Driving wheels, Boxpok	General Steel Castings Corp., Eddystone, Pa.
Axes	Standard Steel Works Co., Burnham, Pa.
Spring washers	National Lock Washer Co., Newark, N. J.
Bearings	Magnus Co., New York
Radial buffer	Franklin Railway Supply Co., New York
Unit safety drawbar	Franklin Railway Supply Co., New York
Hand brake and rear draft gear	W. H. Miner, Inc., Chicago
Foundation brake	American Steel Foundries, Chicago
Air brake	Westinghouse Air Brake Co., Wilmerding, Pa.
Hose	Quaker City Rubber Co., Philadelphia, Pa.
Brake shoes	American Brake Shoe & Foundry Co., New York
Power reverse gear	American Locomotive Co., New York
Boiler steel	Linkens Steel Co., Coatesville, Pa.
Boiler and cylinder jacket	Otis Steel Co., Cleveland, Ohio
Staybolt iron	American Rolling Mill Co., Middletown, Ohio
Staybolts	Ulster Iron Works, Dover, N. J.
Tubes	Flannery Bolt Co., Bridgeville, Pa.
Smokebox netting	Globe Steel Tubes Co., Milwaukee, Wis.
Front-end hinges	W. S. Tyler Company, Cleveland, Ohio
Feedwater heater	Okade Company, Chicago
Superheater and Tangential dryer	Worthington Pump and Machinery Corp., Harrison, N. J.
Steam-heat equipment	Superheater Company, New York
Steam-pipe casing, Reid	Vapor Car Heating Co., Inc., Chicago
Insulation	Lima Locomotive Works, Inc., Lima, Ohio
Gages	Johns-Manville Sales Corp., New York
Valves for superheated steam	Ashton Valve Co., Cambridge, Mass.
Injector checks	Walworth Company, New York
Bushings, Valve chamber	Nathan Mfg. Co., New York
Floating-bushing rod bearings	Hunt-Spiller Mfg. Corp., Boston, Mass.
Fusible plugs	Hunt-Spiller Mfg. Corp., Boston, Mass.
Bronze piston packing rings	Nathan Mfg. Co., New York
Piston-rod and valve-stem packing	Locomotive Finished Material Co., Atchison, Kan.
Valve pull rings; Duplex sectional packing rings	Paxton Mitchell Co., Omaha, Neb.
Grease cellulars	Hunt-Spiller Mfg. Corp., Boston, Mass.
Force-feed and hydrostatic lubricators	Franklin Railway Supply Co., New York
Lubrication, Rod and motion work	Nathan Mfg. Co., New York
Flexible joints on steam-heat, oil and oil-heater lines, McLaughlin	Alemite Corp., Chicago
Multiple throttle	Franklin Railway Supply Co., New York
Booster	American Throttle Co., Inc., New York
Signal Foam-meter	Superheater Company, New York
Headlight and generator	Electro Chemical Engineering Corp., Chicago
Sanders	Pyle National Co., Chicago
Valve Pilot	Vioco Railway Equipment Co., Chicago
Bell ringers	Valve Pilot Corporation, New York
Whistles, steam	Transportation Devices Corp., Indianapolis, Ind.
	Consolidated Ashcroft-Hancock Co., Inc., Bridgeport, Conn.

practice of the builder. The back end of the main rod and the intermediate side-rod connections are fitted with floating bushings, having fixed bushings of Hunt-Spiller gun iron. The bearings on the front and back crank pins are fixed bushings. The locomotives are fitted with the Walschaert valve gear having a maximum travel of $7\frac{1}{4}$ in. They are equipped with the Alco reverse gear and the Valve Pilot for cut-off control. In order to prevent hooking up to a cut-off of less than 25 per cent the quadrant from this point to the center is blanked. The valve-motion parts are of medium steel like the running gear and crank pins, with the exception of the eccentric rod and radius bar which are of mild steel.

The rods and valve motion have Alemite fittings in the grease cups. Driving boxes are fitted with Franklin grease-lubricated cellars, and the cellars on engine-and trailer-truck journals are waste packed for oil lubrication. The cylinders and valves are lubricated from a Nathan eight-feed force-feed lubricator, type DV4, of 20 pints capacity. In addition to the valve and cylinder feeds two feeds lead to each guide. A Nathan Model 1918 hydrostatic lubricator with three feeds is provided for the booster cylinders, the hot-water feed pump and the steam cylinders of the air compressors.

Boiler Mountings

There are two cab turrets. That for saturated steam is on the right side and supplies the injector, the hydrostatic lubricator, the steam heat and the emergency connection for the reverse gear. On the left side is the superheated-steam turret from which steam is supplied to the feedwater pump, the air compressors, the booster, the oil-burner manifold, the Pyle-National turbo-generator and the blower.

Concealed within the cowling over the top of the boiler are the turrets and the headlight turbo-generator. The safety valves and the whistle, the latter disposed horizontally, are placed in wells, open at the top. The top of the dome cover is accessible through a hatch in the cowling and the sandbox occupies a rectangular space built into the cowling, which has a capacity for 2,000 lb. of sand. The smoke lifter around the stack is completely open at the front and top.

In addition to the steam whistle the locomotives have Typhon air whistles which are mounted over the top and at the front of the smokebox.

Unlike many recently built locomotives the two cross-compound air compressors on each of these engines are mounted on the left side of the boiler, partially concealed under the running-board apron. The bell is placed under the smokebox, to the bottom of which it is attached.

The Tender

The tender is of the rectangular type and is designed in cross-section to conform with the exterior of the coaches of the train. It is built up on a cast-steel water-bottom underframe. The tank has a capacity of 22,000 gallons of water and carries 6,275 gallons of fuel oil. The tender is carried on Buckeye six-wheel trucks with 7-in. by 14-in. journals.

The schedule for the Daylight trains will be considerably accelerated over the present running time. The trains will operate over the Southern Pacific Coast Line via San Luis Obispo, a line which has a maximum grade of 2.2 per cent, with grades of 1 per cent over a large part of the run. The trains now being built will be of lightweight construction, with six of the coach body units articulated into three pairs and the remaining six cars each an independent vehicle. Exclusive of the

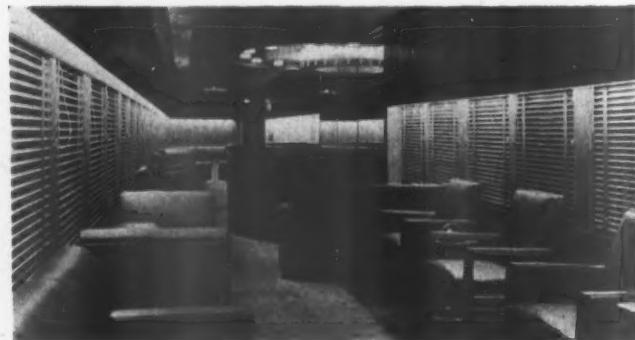
locomotives, the train will weigh 1,187,500 lb. and will be 870 ft. long. It was the need to haul these trains at high speeds under the difficulties imposed by the line that led to the development of a locomotive possessing both high tractive force and the ability to make high speeds on level track.

The general dimensions and weights are given in the table.

Venetian Blinds For Passenger Cars

The accompanying interior view of the lounge car on the "Mercury," the New York Central streamlined steam train, illustrates the adaptation of Ventilighter Venetian blinds on railroad passenger cars. Rattling of these blinds at the high speeds attained by streamlined trains is prevented by design features which include channel-type side guides with a center rubber strip so devised that the slats are snubbed in all positions of angular adjustment. The side channel guides in which the slats are raised and lowered are made of 16-gage aluminum, and are secured with machine screws to the frame of the window. The exposed faces of the guides are finished to match the interior trim of the car.

This Ventilighter blind, which is manufactured by the Simon Ventilighter Company, Inc., New York, N. Y., is an assemblage of parallel $\frac{1}{8}$ -in. by $1\frac{3}{4}$ -in. cedar slats located on $1\frac{1}{2}$ -in. centers, and pivotally suspended in $1\frac{1}{2}$ -in. cloth ladder tape fastened to a concealed overhead shaft of aluminum. This shaft has a diameter of



Ventilighter Venetian Blinds on the Lounge Car of the "Mercury"

$\frac{3}{4}$ in. and is attached to the car frame by friction clamping brackets of the brake-band type. By tilting the shaft, the tapes, and the slats suspended therefrom, any angular position of the slats is obtained. Tilting is accomplished by means of tasseled pull cords, or by a knobbed lever attached to the shaft.

The blinds are operated by two controls, one for tilting the angle of the slats as previously described, and one for raising and lowering. The raising and lowering cords are designed to bring the vanes horizontal, eliminating unnecessary friction in lifting the blind. By eliminating the conventional worm-gear tilt used with Venetian blinds, and using the friction brake principle previously referred to, the head construction of the Ventilighter is such that it raises clear of the interior frame of a double-sash window. This makes it possible to use hinged or removable interior sashes, which can be moved without disturbing the blind when cleaning these sashes.

Failures of

Locomotive Parts*

THE two previous articles in this series have dealt with the failures of piston rods through the taper section which fits in the crosshead, or in the fillet between the shank of the rod and the taper end. It is the purpose of this article to point out additional causes of failures in the taper section of the rod and to summarize the points brought out in the three articles.

The finish of the keyway of a piston rod is of extreme importance. The edges of all keyways should be rounded off with suitable radii, in proportion to the size of the rod and the keyway. These edges must not be beveled or chiseled, but must have a polished, rounded finish, without nicks or breaks. A properly finished edge on a keyway is "a thing of beauty and a joy forever."

There are many ways in which a shopman can get a good finish, with a proper radius, quickly and at a reasonable cost when compared to having to provide a new piston rod every year or two.

Another cause of failure is chargeable to the leaving of pock or punch marks, which were used in laying out the keyway. These should in all cases be removed and this, of course, can only be done by eliminating them in the process of cutting the keyway and rounding off the sharp edges.

It is often the practice when making the keyway to drill three or more holes and then mill or chisel out the remaining metal. Any defect is, of course, hidden from sight when the piston rod is keyed to the crosshead. This in a way is unfortunate, since it is impossible to check up by inspection after the assembly is made.

Occasionally the holes are drilled off center, halfway through the rod, and the hole is then completed by drilling from the opposite side. This leaves a ridge at the center of the keyway, which may start a fatigue crack and cause a failure. I do not know why it is that the drill, properly started, should run off to one side; unless possibly it is because it has not been properly sharpened. This, also, will cause torn walls in the drilled hole, the effects of which may not be removed by the subsequent machining and finishing process and may cause fatigue cracks.

Radiographs which were made of the walls of piston-rod keyways showed change in the density of the steel along the axis of the drilled holes caused by the drilling of the holes, even though the metal had been milled out after the drilling; in other words, the wall of the drilled hole was so torn and work-hardened that the metal was badly distorted and the effects were not entirely removed by the subsequent milling operation.

Tool marks, tears, corrosion and other irregularities when associated with reverse stresses are almost sure to cause fatigue cracks and failure. Stress-corrosion naturally starts much more quickly with a rough surface than with a polished one. It is said that corrosion and tool marks, in conjunction with reverse stresses, will reduce the strength of a part by as much as 50 to 60 per cent. This is something for the designer to think about in making his calculations.

Another difficulty is that the designer may not recognize the importance of indicating the small radii to designate the rounding of the edges of the keyway, and quite

By F. H. Williams†

naturally, the mechanic will not feel called upon to round off these corners if the drawing does not so designate.

Sometimes a keyway may be worn in service and the edges burred, especially near the ends, which with a little careful workmanship could be made as good as new. It may be placed back in the crosshead, however, without this work being done. The key may perhaps ride to one side and thus place an unnecessary strain upon that portion of the rod, and overstress a section which may lack the proper finish and be subject to the development of fatigue cracks.

Instances have been known of keyways on which the oxy-acetylene torch was used to remove surplus metal. No one was the wiser until the rod failed and investigation brought to light the fact that the torch had been used.

Another detail which must not be overlooked is the construction of the key itself. It was the practice formerly to forge these keys to shape from pieces of old steel tires. This practice was changed by purchasing steel similar to tire steel but rolled into bars to nearly the required size. It is only necessary to shape them to the exact size and then heat treat the material, thus insuring high tensile strength and toughness. Complaints were made at one time that some keys were not standing up as they should. Investigation revealed the fact that the heat treatment had been omitted. The difficulty was promptly overcome when the shop forces understood the importance of dealing with the new material properly.

With these introductory remarks as a background, illustrations will be shown of rods which were improperly finished and which failed. Fig. 1, for instance, is a rather extreme case, but shows a rod which was scrapped for defects. The keyway was off center, causing the key to bear on one side and displacing the metal at the end to such an extent that it could not fit the crosshead properly. Stresses were apparently concentrated just above the keyway and stress-corrosion cracks were started. While this was the primary cause of the failure, the sharp edges of the keyway and the punch marks were also potential sources of failure.

A piston rod which failed through the taper fit, primarily because of the sharp edges of the keyway, is shown in Figs. 2 and 3. It will be noted, also, that the material was badly chafed or worn near the edges of the keyway. The point where the difficulty started, at one side of the keyway, is clearly indicated by the fatigue crack nucleus in Fig. 3.

The piston rod shown in Fig. 4 was scrapped because of the crack X-X. Here again, the edges of the keyway were not rounded off and the chafed material indicates that the rod was not properly fitted in the crosshead. The fatigue crack started from the edge of the drilled hole in the end of the keyway, the conditions apparently being complicated by the poor fit, which caused an abrasion or flow of surface metal. These poor fits have been largely overcome by using the plug-and-collar gages mentioned in the previous article, and thus standardizing the taper for the fit. It will be noted also from the photograph, that the edges of the keyway at the ends are badly burred. By working with the gages

* Part 9 of an article which began in the May, 1936, issue.
† Assistant test engineer, Canadian National Railways.

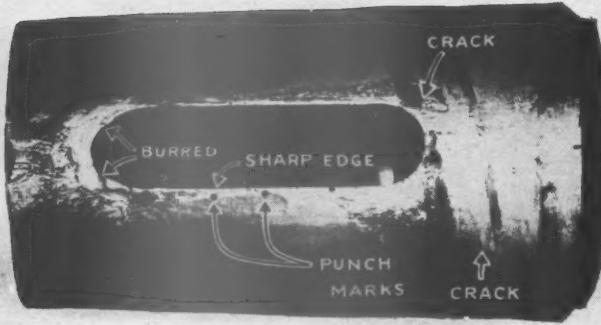


FIG. 1



FIG. 3

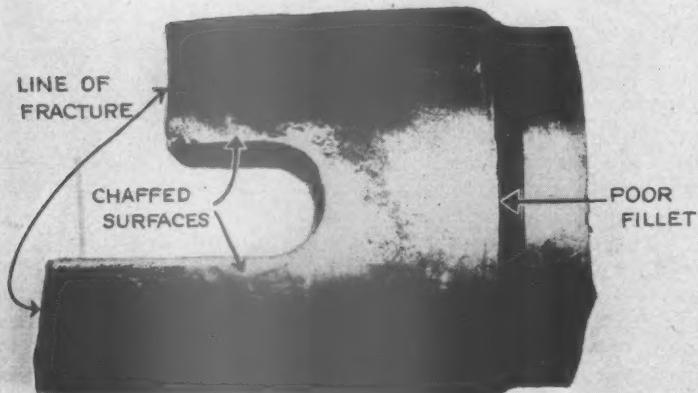


FIG. 2

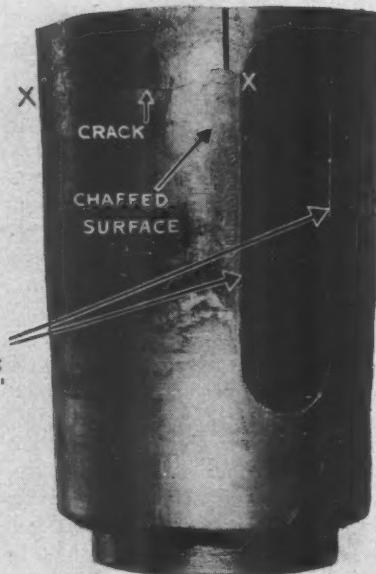


FIG. 4

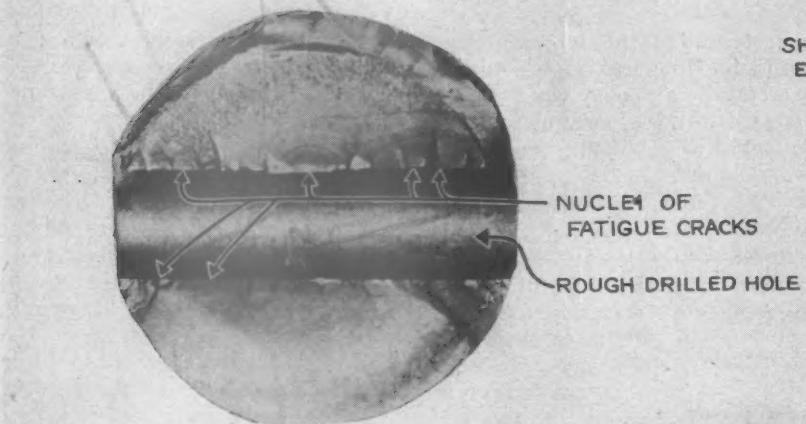


FIG. 5

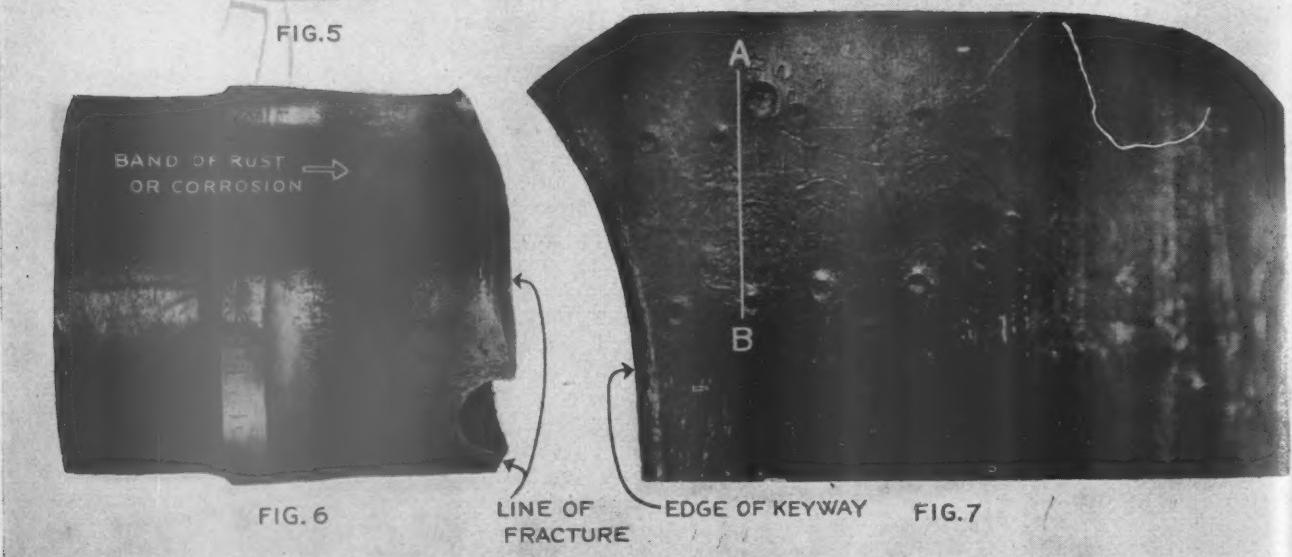


FIG. 6

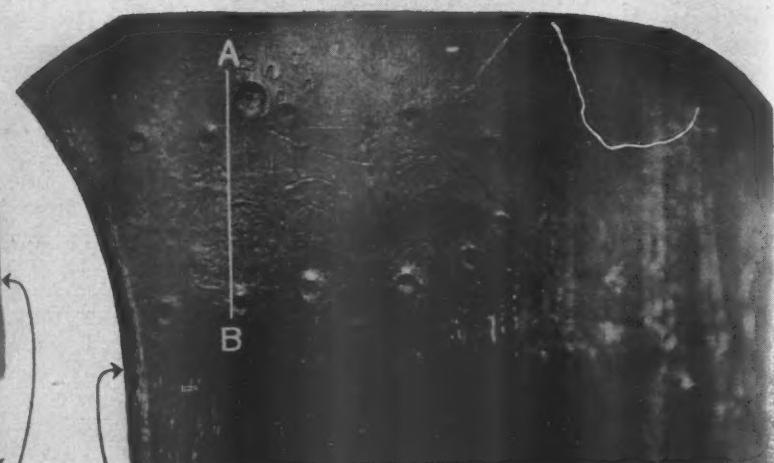


FIG. 7

SURFACE OF TAPER FIT

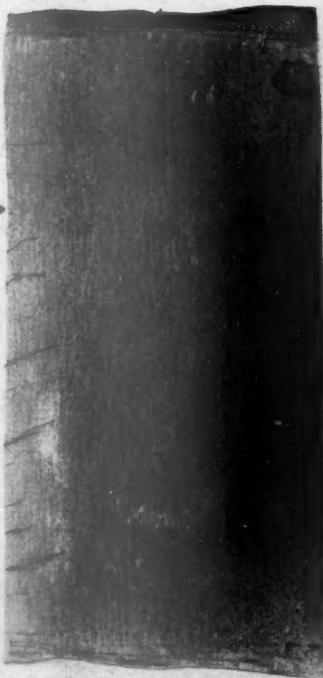


FIG. 8

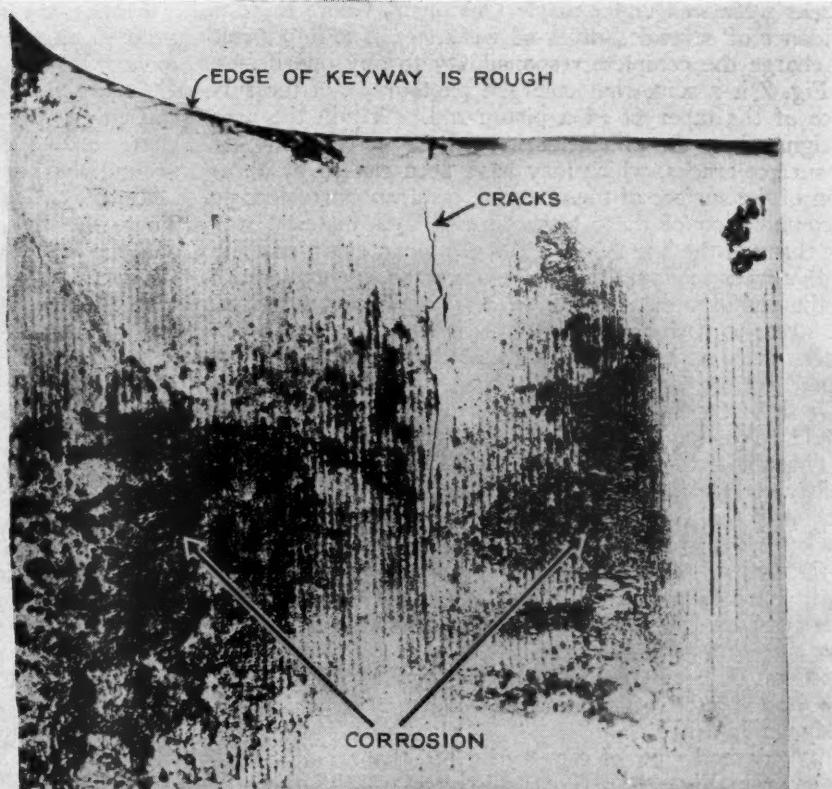


FIG. 11

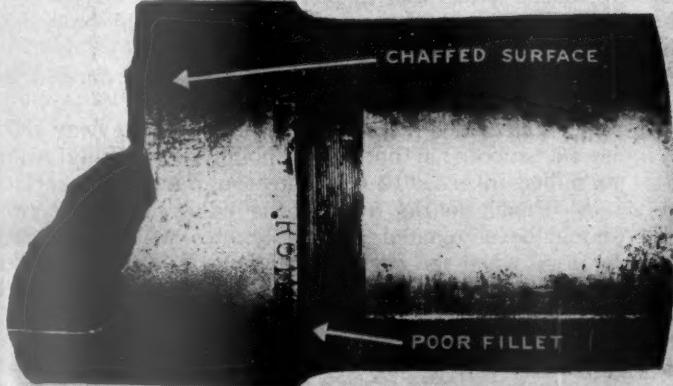


FIG. 9

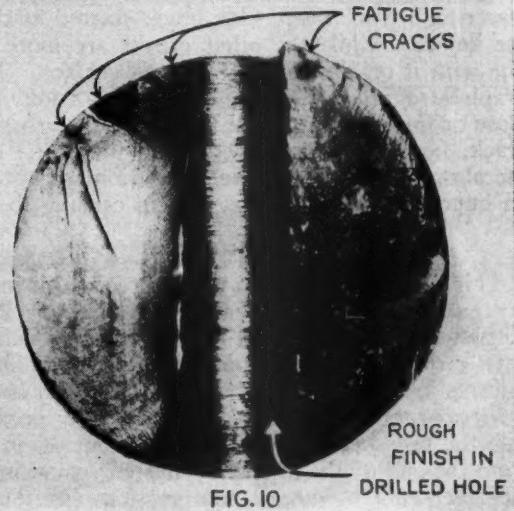


FIG. 10

Fig. 8—Cross section (enlarged) of the piston rod through section A-B, Fig. 7. Note the cracks extending inward from the surface of the taper fit of the piston rod. Fig. 9—Fatigue cracks started from the rough surface on the taper fit of the piston rod. Fig. 10—Fractured end of the piston rod shown in Fig. 9, which failed in service. Fig. 11—Enlarged view of the surface of a piston rod which failed in the taper fit. Note the rough edges of the keyway and the corrosion, which is indicated by the dark areas.

1—Taper end of a piston rod which was scrapped because of the cracks noted. Fig. 2—Piston rod which broke through taper fit. Note that the material is badly chafed alongside the edges of the keyway. Fig. 3—Fractured end of the piston rod shown in Fig. 2. The fatigue crack started in the chafed section. Note that the hole in the center of the keyway was drilled off center. Fig. 4—Piston rod which was scrapped because of the crack X-X. Fig. 5—Badly drilled hole at the end of a keyway of a piston rod which failed in service. Fig. 6—Enlarged view of the taper end of the piston rod, the fractured face of which is shown in Fig. 5. Fig. 7—Enlarged view of the surface of the taper fit of a defective piston rod. Note the surface cracks in the area within the punch marks.

and to a standard taper, this condition has largely been done away with.

An excellent example of the effects of badly drilled holes at the ends of keyways is shown in Figs. 5 and 6. It will be seen that the fatigue cracks, and there are many of them, all start from the walls of the drilled hole. The roughnesses or tears in the wall of the drilled hole do not appear quite as clearly as they should, because in the endeavor to focus on the fatigue cracks, the wall at the end of the keyway was thrown a little out of focus. The band of rust or corrosion, in Fig. 6, is evidence of a poorly fitted rod, and this may have been a factor in concentrating excessive reverse stresses on the walls of the drilled hole, although the band of rust may have resulted because of the rod working after the fatigue

cracks were well under way. Obviously, where there is evidence of several sources of weakness, it is impossible to charge the complete responsibility to any one defect.

Fig. 7 is a somewhat enlarged photograph of the surface of the taper fit of a piston rod. Within the area designated by the punch marks, will be noted a number of surface cracks, which may have been caused by abrasion of the surface of the material, or stress-corrosion, or a combination of these two causes. This material was cut through the line A-B, and Fig. 8 is an enlarged view of this cross section. While the appearance of the cracks in the photographs might indicate that they were caused by stress-corrosion, yet the area is one in which such cracks are not usually found, and they may have been caused by the abrasion of the crosshead, because of the poor fit of the rod. A properly machined and fitted rod would have eliminated both of these causes.

The abrasion or corrosion on a rod which failed, is clearly evident in Fig. 9. It will be noted from the cross section of this break that there were a number of fatigue cracks, which started from the rough surface. The hole at the end of the keyway was also roughly drilled and might have caused the failure. It will be seen that the fillet between the shank of the rod and the tapered section is rough machined only. It is only fair to say that this is an unusual condition and such practice would not now be tolerated. The fractured end of this piston rod is shown in Fig. 10.

An enlarged view of a part of a rod that was cracked is shown in Fig. 11. Here, again, it is difficult to indicate the exact cause of the failure. The edge of the keyway is rough and almost sharp. The taper fit of the rod was rough machined. One crack started at the edge of the keyway, while the other cracks are more or less in line with it on the rough machined surface. The photograph also indicates considerable corrosion due to the loose or improper fitting of the rod in the crosshead. The crack, however, is removed from the worst portion of the abraded surface, so that corrosion was probably not an important factor in this case in causing the cracks.

Summary

This article and the two which preceded it in the January and February numbers of the *Railway Mechanical Engineer*, have illustrated broken rods, or defects which have required the scrapping of the rod. Outstanding failures in the tapered section of the piston rod are:

Stress-corrosion cracks—These usually occur just inside the crosshead fit on the rod, about $\frac{1}{2}$ in. to $\frac{3}{4}$ in. from the end of the keyway. The corrosion is caused by the steel rubbing under compression (frictional corrosion).

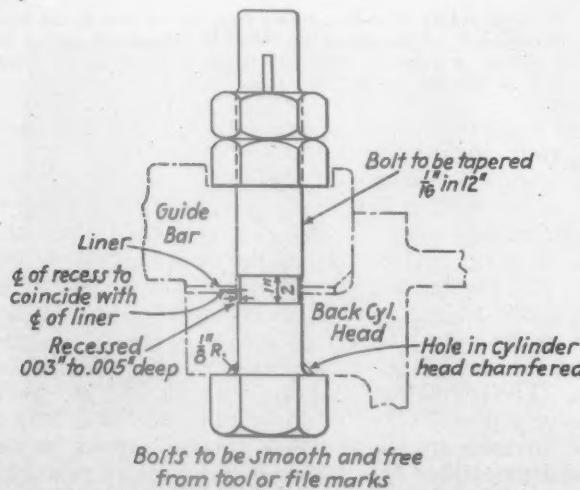


Fig. 12—Undercutting as applied to guide-bar bolts

Cracks starting from tool marks—These are due to grooves on the surface caused by improperly sharpened tools.

Cracks starting from cold-worked surfaces—These are caused by using the wrong taper, allowing the rod to chafe in the crosshead fit. They are usually located around the keyway and just inside the crosshead.

Cracks starting from sharp edges of the keyway—These usually occur between the center of the keyway and the end toward the larger diameter of the taper.

Cracks starting from punch marks—These punch marks are used in laying out the keyway and occasionally are not removed by the machining operations. Such a crack occasionally starts from letters or numbers which are stamped on the taper fit at its large end.

Cracks starting from roughly drilled holes—These cracks start in the walls of the drilled hole.

Cracks starting from holes drilled off center—These are much the same as those for the roughly drilled holes above mentioned.

Cracks starting from roughly milled keyways—These, of course, are in the side walls of the keyway.

Cracks starting from corrosion bands—The corrosion bands are caused by a poor fit or wrong taper of the piston rod in the crosshead. This may be due to pressure (frictional corrosion) or to atmospheric corrosion.

All of the above-mentioned causes of failure may be largely eliminated by more careful workmanship.

Recommendations

Summing up the three articles on piston-rod failures, the following practices are commended:

1—The taper fits of piston rods to the crossheads should be carefully and accurately made, with the aid of master plugs and master collars.

2—The taper fits on piston rods should be finished free from all tool marks and scores.

3—The edges of the keyways should be rounded with proper radii.

4—The drilled holes used in making the keyway should be cut smooth; if not, they should be carefully reamed or milled in order to eliminate rough and torn surfaces.

5—Punch marks around the edges of the keyways should be eliminated; obviously, this will automatically be done when the edges of the keyway are rounded off, unless an error is made and the keyway is wrongly located.

6—Burrs at the ends of the keyways should not be tolerated.

7—Undercuts of proper width and diameter should be made on the taper fit of the piston rods, between the edge of the crosshead and the keyway. A suggested method of doing this was illustrated in the article in the *Railway Mechanical Engineer* of January, 1937, page 19. A similar practice in the application of guide-bar bolts is illustrated in Fig. 12. The undercutting should be made from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. wide and from .003 in. to .005 in. in depth. It should lie between the end of the keyway and the taper fit within the crosshead. This undercutting should have proper fillets at both ends and must be polished and free from scratches. If this band is rolled instead of undercut, care must be taken to free the surface from all tool marks and torn metal before the rolling is done. As indicated in the previous article, this undercutting is done to prevent stress-corrosion cracks.

These comments on undercutting apply also to axles and practically all press fits where the surfaces under pressure are subject to reverse stresses. The author has known of shafts failing just inside the collar because of stress-corrosion.

Remember that a perfect fit is a lasting fit.

Diesel-Electric Locomotive

Projected Repair Costs



IN 1932 the Northampton & Bath, which operates between Northampton, Pa., and Bath Junction, Pa., over a rolling profile with a maximum grade 1.8 per cent for approximately 2,500 ft. and an equivalent grade of about 1 per cent against heavy traffic, decided to use only Diesel-electric locomotives. This decision was based upon performance of Diesel-electric equipment as guaranteed by the manufacturers, and the evident economies of operation derived through a comprehensive study by the road's engineering department of available data.

In determining operating costs of Diesel-electric motive power it was decided to break them down into six major expenses, viz., wages, fuel, lubrication, supplies, enginehouse expense and repairs. Of these, all may be more or less readily determined from actual records, with the exception of repair costs, which fluctuate from month to month, year to year and with light and heavy overhauls. It is a well-known fact that steam locomotive repair costs rise with the locomotive age, and it may be expected that Diesel-electric locomotive repair costs will rise in a similar manner but at a lower rate of increase. It became essential in preparing the data given herein to determine the actual repair costs over a period of years if a real measure of savings were to be ascertained.

It has been fairly well established that Diesel-electric locomotive repairs are divided into three major divisions:

1. Mechanical repairs covering trucks, engineman's and engine room cabs, air-brake equipment and miscellaneous mechanical auxiliary equipment.

2. Electrical repairs covering traction motors, generators, control equipment, etc.

3. Diesel repairs covering the Diesel units together with their major intimate auxiliaries.

Straight electric operation has determined the economic life of the equipment listed under the mechanical and electrical divisions. However, the life of Diesel

Projected repair costs over a twenty-five-year period for an 800-hp. Diesel-electric locomotive. Includes itemization of parts replaced, labor hours, material costs and labor charges

units is still subject to argument, inasmuch as Diesel-electric locomotives have not been in service long enough for the compilation of records showing actual repair costs over a long period of time.

Therefore, in compiling the repair cost presented herein it was thought that if the repair-cost trend curve for straight electric locomotives could be determined, and

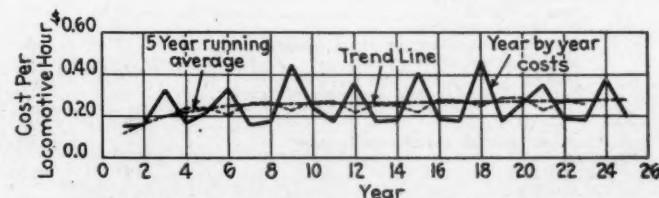


Fig. 1—Average repair costs of mechanical equipment

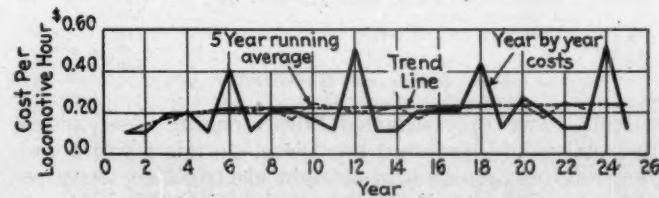


Fig. 2—Average repair costs of electrical equipment

Table I—Twenty-Five-Year Projected Repair Costs for an 800-Hp. Diesel Electric Locomotive

FIRST YEAR—7,000 Hrs.			Material cost			Labor hours			Material cost			Labor hours		
Mechanical:														
Air compressors (prorated)		\$40		30		Diesel engines:								
Air brake equipment (prorated)		30		40		7,000 hrs.								
True tires (twice a year)				60		21,000 hrs.:								
Brake shoes (6 sets)		120				Disassemble and assemble								
Hub liners		215		50		New pistons								
Sanders (prorated)		4		8		New liners								
Window wipers		4				Connecting-rod bearings								
Annual maintenance		50		660		Push rods, etc.								
		463		848		Polish and true up crank pins								
Electrical:						Puralators								
Traction motors:						Cylinder-head water connections								
Brushes		25												
Armature and field coils (prorate units one motor)		100		20										
Canvas bellows		3		10										
Generator:														
Brushes		20												
Exciters:														
Brushes		5												
Wiring:														
Power and control (prorated)		50		25										
Control:														
Miscellaneous fixtures		100												
Air compressor motors:														
Miscellaneous		20												
Annual maintenance		30		480										
		353		535										
Diesel engines:														
Rings		60		132										
Valve grinding and reseating (twice per year)		50		300										
Gears (prorated)		40												
Miscellaneous gaskets		20												
Miscellaneous ball bearings (prorated)		20												
Miscellaneous springs		10												
Annual maintenance		110		840										
		310		1,272										
Totals		1,126		2,655										
Labor cost at 68 cents per hour		1,805.40												
Annual total cost		2,931.40												
Annual cost per hour		0.419												
SECOND YEAR—14,000 Hrs.			Material cost			Labor hours			Material cost			Labor hours		
Mechanical:														
7,000 hrs.		\$463		848										
14,000 hrs.:														
Foot board (wood)		5		12										
Arm rests		10		5										
Air hose		5												
		20		17										
Increase annual maintenance, labor														
Electrical:														
7,000 hrs.		353		535										
14,000 hrs.:		None		None										
Increase annual maintenance, labor														
Diesel engines:														
7,000 hrs.		310		1,272										
14,000 hrs.:														
Renew atomizer nozzles and needles		120												
		120												
Increase annual maintenance, labor														
Totals		1,266		2,722										
Labor cost at 68 cents per hour		1,850.96												
Annual total cost		3,116.96												
Annual cost per hour		0.445												
THIRD YEAR—21,000 Hrs.			Material cost			Labor hours			Material cost			Labor hours		
Mechanical:														
7,000 hrs.		\$463		793										
21,000 hrs.:														
New tires, polish journals and reface wheel hubs		420		250										
Coupler knuckles		12		1										
Rebabbitt brasses		75												
Seat cushions		10		5										
Brake-pipe strainer		5		5										
Cleaning miscellaneous truck parts		10		140										
Miscellaneous truck repairs														
Jacking cab up and down		20		175										
Partial disassembly and assembly of trucks		30		275										
		582		991										
Increase annual maintenance, labor														
Electrical:														
7,000 hrs.		353		495										
21,000 hrs.:														
Light wiring		20		80										
Traction motors:														
Miscellaneous plates, leads and bolts, etc.		80		40										
Armature bearings		300												
Disassemble and assemble		20		200										
		420		320										
Increase annual maintenance, labor														
SIXTH YEAR—42,000 Hrs.			Material cost			Labor hours			Material cost			Labor hours		
Mechanical:														
7,000 hrs.		\$463		793										
14,000 hrs.		20		17										
21,000 hrs.		582		991										
42,000 hrs.		None		None										
Increase annual maintenance, labor														

(Table continued on opposite page)

to this curve the estimated Diesel engine costs added, the total would represent the Diesel-electric repair trend. A careful examination of straight electric locomotive repair costs showed that costs relative to repairs of parts

of equipment of straight electric locomotives not common to Diesel-electric locomotives could not be separated readily from the available figures for straight electric locomotive maintenance. Therefore, this method

Table I — Twenty-Five-Year Projected Repair Costs (Continued)

	Material cost	Labor hours	Material cost	Labor hours
Electrical:			Electrical:	
7,000 hrs.	\$353	495	7,000 hrs.	\$353
14,000 hrs.	None	None	21,000 hrs.	420
21,000 hrs.	400	120	63,000 hrs.:	320
42,000 hrs.:			Generators:	
Traction motors:			Bearings	100
Pinions	70	16		20
Commutators slotting, turning, dipping, banding and baking	700	40		
Axle bearings	220	...		
Generators:				
Disassemble and assemble	...	80		
Commutator slotting, turning, dipping, banding and baking	400	20		
Exciters:				
Disassemble and assemble	...	10		
Commutator slotting, turning, dipping, banding and baking	150	10		
	1,540	176		
Increase annual maintenance, labor	...	60		
Diesel engines:				
7,000 hrs.	285	1,052		
14,000 hrs.	120	...		
21,000 hrs.	2,180	544		
42,000 hrs.:				
Renew vibration discs	50	...		
Renew rocker-arm bearings	60	...		
Renew fuel-pump straps	180	...		
Renew lub. gov. and scavenger-pump gear and shafts	100	...		
Renew tappet plungers, guides, springs and roller bushings complete	300	50		
Crankshaft bearings	380	...		
	1,070	50		
Increase annual maintenance, labor	...	105		
Totals	7,013	4,485		
Labor cost at 68 cents per hour	3,049.80	...		
Annual total cost	10,062.80	...		
Annual cost per hour	1.438	...		
SEVENTH YEAR—49,000 Hrs.				
	Material cost	Labor hours	Material cost	Labor hours
Mechanical:			Mechanical:	
7,000 hrs.	\$463	848	7,000 hrs.	\$463
49,000 hrs.	None	None	14,000 hrs.	20
Increase annual maintenance, labor	...	99	35,000 hrs.	255
Electrical:			70,000 hrs.:	250
7,000 hrs.	353	535	Bell ringer	10
49,000 hrs.	None	None	Headlight reflectors	20
Increase annual maintenance, labor	...	72	Brake-pipe cut-out cocks	20
Diesel engines:			Engineman's cab floor (wood)	10
7,000 hrs.	310	1,272		40
49,000 hrs.:	50	...		
Nugent strainer baskets	50	...		
	50	126		
Increase annual maintenance, labor	...	126		
Totals	1,176	2,952		
Labor cost at 68 cents per hour	2,007.36	...		
Annual total cost	3,183.36	...		
Annual cost per hour	0.455	...		
EIGHTH YEAR—56,000 Hrs.				
	Material cost	Labor hours	Material cost	Labor hours
Mechanical:			Mechanical:	
7,000 hrs.	\$463	848	7,000 hrs.	\$463
14,000 hrs.	20	17	77,000 hrs.	None
28,000 hrs.	20	20	Increase annual maintenance, labor	165
56,000 hrs.	None	None	Electrical:	
Increase annual maintenance, labor	...	116	7,000 hrs.	363
Electrical:			77,000 hrs.	None
7,000 hrs.	353	535	Increase annual maintenance, labor	120
14,000 hrs.	None	None	Diesel engines:	
28,000 hrs.	650	50	7,000 hrs.	310
56,000 hrs.	None	None	77,000 hrs.	None
Increase annual maintenance, labor	...	84	Increase annual maintenance, labor	210
Diesel engines:			Totals	1,126
7,000 hrs.	310	1,272	Labor cost at 68 cents per hour	3,150
14,000 hrs.	120	...	Annual total cost	2,142.00
28,000 hrs.	550	40	Annual cost per hour	0.467
56,000 hrs.	None	None		
Increase annual maintenance, labor	...	147		
Totals	2,486	3,129		
Labor cost at 68 cents per hour	2,127.72	...		
Annual total cost	4,613.72	...		
Annual cost per hour	0.659	...		
NINTH YEAR—63,000 Hrs.				
	Material cost	Labor hours	Material cost	Labor hours
Mechanical:			Mechanical:	
7,000 hrs.	\$463	793	7,000 hrs.	\$463
21,000 hrs.	552	716	14,000 hrs.	20
63,000 hrs.:			21,000 hrs.	582
Trucks:			28,000 hrs.	20
Axles	300	60	42,000 hrs.	None
Complete disassembly and assembly of trucks	50	450	84,000 hrs.:	None
Federal shoe	20	24	Male center-plate wearing plate	25
Springs retemper	100	...		40
Spring hangers	80	...		
Spring-hanger pins	20	...		
Spring-hanger keys	20	...		
Brake heads	20	...		
King bolt	20	...		
	630	534		
Increase annual maintenance, labor	...	132		
TENTH YEAR—70,000 Hrs.				
	Material cost	Labor hours	Material cost	Labor hours
Mechanical:			Mechanical:	
7,000 hrs.	\$463	848	7,000 hrs.	\$463
14,000 hrs.	20	17	14,000 hrs.	20
35,000 hrs.	255	250	35,000 hrs.	250
70,000 hrs.:			70,000 hrs.:	
Bell ringer	10	5	Booster fuel-pump motors	50
Headlight reflectors	20	...	Scavenger fuel-pump motors	50
Brake-pipe cut-out cocks	20	10	Radiator blower motors	75
Engineman's cab floor (wood)	10	40	Traction motor blowers	200
	60	55		
Increase annual maintenance, labor	...	148		
Electrical:				
7,000 hrs.	353	535		
14,000 hrs.	None	None		
35,000 hrs.	None	None		
70,000 hrs.:				
Increase annual maintenance, labor	...	108		
Diesel engines:				
7,000 hrs.	310	1,272		
14,000 hrs.	120	...		
35,000 hrs.	1,262	180		
70,000 hrs.:				
Water-pump bodies	24	10		
Cuno strainers	50	...		
Mufflers	40	...		
	114	10		
Increase annual maintenance, labor	...	189		
Totals	3,332	3,612		
Labor cost at 68 cents per hour	2,456.16	...		
Annual total cost	5,788.16	...		
Annual cost per hour	0.827	...		
ELEVENTH YEAR—77,000 Hrs.				
	Material cost	Labor hours	Material cost	Labor hours
Mechanical:			Mechanical:	
7,000 hrs.	\$463	848	7,000 hrs.	\$463
77,000 hrs.	None	None	77,000 hrs.	None
Increase annual maintenance, labor	...	165		
Electrical:				
7,000 hrs.	363	535		
77,000 hrs.	None	None		
Increase annual maintenance, labor	...	120		
Diesel engines:				
7,000 hrs.	310	1,272		
77,000 hrs.	None	None		
Increase annual maintenance, labor	...	210		
Totals	1,126	3,150		
Labor cost at 68 cents per hour	2,142.00	...		
Annual total cost	3,268.00	...		
Annual cost per hour	0.467	...		
TWELFTH YEAR—84,000 Hrs.				
	Material cost	Labor hours	Material cost	Labor hours
Mechanical:			Mechanical:	
7,000 hrs.	\$463	793	7,000 hrs.	\$463
14,000 hrs.	20	17	14,000 hrs.	20
21,000 hrs.	582	991	21,000 hrs.	582
28,000 hrs.	20	20	28,000 hrs.	20
42,000 hrs.	None	None	42,000 hrs.	None
84,000 hrs.:				
Male center-plate wearing plate	25	40		
	25	40		
Increase annual maintenance, labor	...	182		
Electrical:				
7,000 hrs.	353	495		
14,000 hrs.	None	None		
21,000 hrs.	400	120		
28,000 hrs.	650	50		
42,000 hrs.	1,540	176		
84,000 hrs.:				
Increase annual maintenance, labor	...	132		

Table 1—Twenty-Five-Year Projected Repair Costs (Continued)

	Material cost	Labor hours		Material cost	Labor hours
Diesel engines:			Totals	\$2,486	3,525
7,000 hrs.	\$285	1,052	Labor cost at 68 cents per hour	2,397.00	
14,000 hrs.	120	...	Annual total cost	4,883.00	
21,000 hrs.	2,180	544	Annual cost per hour	0.698	
28,000 hrs.	550	40			
42,000 hrs.	1,070	50	SEVENTEENTH YEAR—119,000 Hrs.		
84,000 hrs.	None	None	Mechanical:		
Increase annual maintenance, labor	231		7,000 hrs.	\$463	848
Totals	8,258	4,933	119,000 hrs.	None	None
Labor cost at 68 cents per hour	3,354.44	...	Increase annual maintenance, labor	264	
Annual total cost	11,612.44	...	Electrical:		
Annual cost per hour	1,659	...	7,000 hrs.	353	535
			119,000 hrs.	None	None
			Increase annual maintenance, labor	192	
THIRTEENTH YEAR—91,000 HRS.			Diesel engines:		
Mechanical:			7,000 hrs.	310	1,272
7,000 hrs.	\$463	848	119,000 hrs.	None	None
91,000 hrs.	None	None	Increase annual maintenance, labor	336	
Increase annual maintenance, labor	198		Totals	1,126	3,447
Electrical:			Labor cost at 68 cents per hour	2,343.96	
7,000 hrs.	353	535	Annual total cost	3,469.96	
91,000 hrs.	None	None	Annual cost per hour	0.496	
Increase annual maintenance, labor	144				
Diesel engines:			EIGHTEENTH YEAR—126,000 Hrs.		
7,000 hrs.	310	1,272	Mechanical:		
91,000 hrs.	None	None	7,000 hrs.	\$463	793
Increase annual maintenance, labor	252		14,000 hrs.	20	17
Totals	1,126	3,249	21,000 hrs.	552	716
Labor cost at 68 cents per hour	2,209.32	...	42,000 hrs.	None	None
Annual total cost	3,335.32	...	63,000 hrs.	630	534
Annual cost per hour	0.476	...	126,000 hrs.	None	None
			Increase annual maintenance, labor	280	
FOURTEENTH YEAR—98,000 HRS.			Electrical:		
Mechanical:			7,000 hrs.	353	495
7,000 hrs.	\$463	848	14,000 hrs.	None	None
14,000 hrs.	20	17	21,000 hrs.	400	120
49,000 hrs.	None	None	42,000 hrs.	1,540	176
98,000 hrs.	None	None	63,000 hrs.	100	20
Increase annual maintenance, labor	214		126,000 hrs.	None	None
Electrical:			Increase annual maintenance, labor	204	
7,000 hrs.	353	535	Diesel engines:		
14,000 hrs.	None	None	7,000 hrs.	285	1,052
49,000 hrs.	None	None	14,000 hrs.	120	...
98,000 hrs.	None	None	21,000 hrs.	2,180	544
Increase annual maintenance, labor	156		42,000 hrs.	1,070	50
Diesel engines:			63,000 hrs.	2,010	86
7,000 hrs.	310	1,272	126,000 hrs.	None	None
14,000 hrs.	120	...	Increase annual maintenance, labor	357	
49,000 hrs.	50	...	Totals	9,723	5,444
98,000 hrs.	None	None	Labor cost at 68 cents per hour	3,701.92	
Increase annual maintenance, labor	273		Annual total cost	13,424.92	
Totals	1,316	3,315	Annual cost per hour	1.918	
Labor cost at 68 cents per hour	2,254.20	...			
Annual total cost	3,570.20	...	NINETEENTH YEAR—133,000 HRS.		
Annual cost per hour	0.61	...	Mechanical:		
			7,000 hrs.	\$463	848
FIFTEENTH YEAR—105,000 HRS.			133,000 hrs.	None	None
Mechanical:			Increase annual maintenance, labor	297	
7,000 hrs.	\$463	793	Electrical:		
21,000 hrs.	582	991	7,000 hrs.	353	535
35,000 hrs.	255	250	133,000 hrs.	None	None
105,000 hrs.	None	None	Increase annual maintenance, labor	216	
Increase annual maintenance, labor	231		Diesel engines:		
Electrical:			7,000 hrs.	310	1,272
7,000 hrs.	353	495	133,000 hrs.	None	None
21,000 hrs.	420	320	Increase annual maintenance, labor	378	
35,000 hrs.	None	None	Totals	1,126	3,546
105,000 hrs.	None	None	Labor cost at 68 cents per hour	2,411.28	
Increase annual maintenance, labor	168		Annual total cost	3,537.28	
Diesel engines:			Annual cost per hour	0.505	
7,000 hrs.	285	1,052			
21,000 hrs.	2,180	544	TWENTIETH YEAR—140,000 HRS.		
35,000 hrs.	1,262	180	Mechanical:		
105,000 hrs.:	2,700	...	7,000 hrs.	\$463	848
Crankshafts	2,700	...	14,000 hrs.	20	17
			28,000 hrs.	20	20
Increase annual maintenance, labor	294		35,000 hrs.	255	250
Totals	8,500	5,318	70,000 hrs.	60	55
Labor cost at 68 cents per hour	3,616.24	...	140,000 hrs.	None	None
Annual total cost	12,116.24	...	Increase annual maintenance, labor	314	
Annual cost per hour	1.731	...			
SIXTEENTH YEAR—112,000 HRS.			(Table continued on opposite page)		
Mechanical:					
7,000 hrs.	\$463	848			
14,000 hrs.	20	17			
28,000 hrs.	20	...			
56,000 hrs.	None	None			
112,000 hrs.	None	None			
Increase annual maintenance, labor	248				
Electrical:					
7,000 hrs.	353	535			
14,000 hrs.	None	None			
28,000 hrs.	650	50			
56,000 hrs.	None	None			
112,000 hrs.	None	None			
Increase annual maintenance, labor	180				
Diesel engines:					
7,000 hrs.	310	1,272			
14,000 hrs.	120	...			
28,000 hrs.	550	40			
56,000 hrs.	None	None			
112,000 hrs.	None	None			
Increase annual maintenance, labor	315				

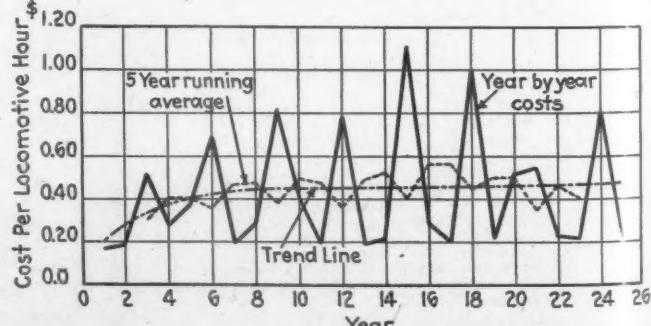


Fig. 3—Average repair costs of the Diesel engine

Table I — Twenty-Five-Year Projected Repair Costs (Continued)

			TWENTY-FOURTH YEAR—168,000 HRS.		
	Material cost	Labor hours		Material cost	Labor hours
Electrical:			Mechanical:		
7,000 hrs.	\$353	535	7,000 hrs.	\$463	793
14,000 hrs.	None	None	14,000 hrs.	20	17
28,000 hrs.	650	50	21,000 hrs.	582	991
35,000 hrs.	None	None	28,000 hrs.	20	20
70,000 hrs.	375	...	42,000 hrs.	None	None
140,000 hrs.	None	None	56,000 hrs.	None	None
Increase annual maintenance, labor.	...	228	84,000 hrs.	25	40
Diesel engines:			168,000 hrs.	None	None
7,000 hrs.	310	1,272	Increase annual maintenance, labor.	...	380
14,000 hrs.	120	...			
28,000 hrs.	550	40			
35,000 hrs.	1,262	180			
70,000 hrs.	114	10			
140,000 hrs.	None	None			
Increase annual maintenance, labor.	...	399			
Totals	4,552	4,218			
Labor cost at 68 cents per hour.	2,868.24	...			
Annual total cost.	7,420.24	...			
Annual cost per hour.	1.06	...			
TWENTY-FIRST YEAR—147,000 HRS.			TWENTY-FIRST YEAR—147,000 HRS.		
	Material cost	Labor hours		Material cost	Labor hours
Mechanical:			Mechanical:		
7,000 hrs.	\$463	793	7,000 hrs.	353	493
21,000 hrs.	582	991	14,000 hrs.	None	None
49,000 hrs.	None	None	21,000 hrs.	400	120
147,000 hrs.	None	None	28,000 hrs.	650	50
Increase annual maintenance, labor.	...	330	42,000 hrs.	1,540	176
Electrical:			56,000 hrs.	None	None
7,000 hrs.	353	495	84,000 hrs.	None	None
21,000 hrs.	420	320	168,000 hrs.	None	None
49,000 hrs.	None	None	Increase annual maintenance, labor.	...	276
147,000 hrs.	None	None			
Increase annual maintenance, labor.	...	240			
Diesel engines:			Diesel engines:		
7,000 hrs.	285	1,052	7,000 hrs.	285	1,052
21,000 hrs.	2,180	544	14,000 hrs.	120	...
49,000 hrs.	50	...	21,000 hrs.	2,180	544
147,000 hrs.	None	None	28,000 hrs.	550	40
Increase annual maintenance, labor.	...	420	42,000 hrs.	1,070	50
Totals	4,333	5,185	56,000 hrs.	None	None
Labor cost at 68 cents per hour.	3,525.80	...	84,000 hrs.	None	None
Annual total cost.	7,858.80	...	168,000 hrs.	None	None
Annual cost per hour.	1.123	...	Increase annual maintenance, labor.	...	
TWENTY-SECOND YEAR—154,000 HRS.			TWENTY-FIFTH YEAR—175,000 HRS.		
	Material cost	Labor hours		Material cost	Labor hours
Mechanical:			Mechanical:		
7,000 hrs.	\$463	848	7,000 hrs.	\$463	848
14,000 hrs.	20	17	35,000 hrs.	Omit	Omit
77,000 hrs.	None	None	175,000 hrs.	None	None
154,000 hrs.	None	None	Increase annual maintenance, labor.	...	396
Increase annual maintenance, labor.	...	346			
Electrical:			Electrical:		
7,000 hrs.	353	535	7,000 hrs.	353	535
14,000 hrs.	None	None	35,000 hrs.	Omit	Omit
77,000 hrs.	None	None	175,000 hrs.	None	None
154,000 hrs.	None	None	Increase annual maintenance, labor.	...	288
Increase annual maintenance, labor.	...	252			
Diesel engines:			Diesel engines:		
7,000 hrs.	310	1,272	7,000 hrs.	310	1,272
14,000 hrs.	120	...	35,000 hrs.	Omit	Omit
77,000 hrs.	None	None	175,000 hrs.	None	None
154,000 hrs.	None	None	Increase annual maintenance, labor.	...	504
Increase annual maintenance, labor.	...	441			
Totals	1,266	3,711	Totals	1,126	3,843
Labor cost at 68 cents per hour.	2,523.48	...	Labor cost at 68 cents per hour.	2,613.24	...
Annual total cost.	3,789.48	...	Annual total cost.	3,739.24	...
Annual cost per hour.	0.541	...	Annual cost per hour.	0.534	...
TWENTY-THIRD YEAR—161,000 HRS.			Hours at end of period		
	Material cost	Labor hours	Year	Material	Labor
Mechanical:				hours per hour	Total
7,000 hrs.	\$463	848	1	\$463	\$576.64
161,000 hrs.	None	None	2	483	1,082.76
Increase annual maintenance, labor.	...	346	3	1,045	1,235.56
Electrical:			4	503	1,338.80
7,000 hrs.	353	535	5	718	1,509.52
161,000 hrs.	None	None	6	1,065	2,345.44
Increase annual maintenance, labor.	...	264	7	49,000	1,106.96
Diesel engines:			8	503	1,183.68
7,000 hrs.	310	1,272	9	1,645	3,124.00
161,000 hrs.	None	None	10	798	1,694.24
Increase annual maintenance, labor.	...	441	11	91,000	1,151.84
Totals	1,126	3,727	12	84,000	2,499.24
Labor cost at 68 cents per hour.	2,534.36	...	13	1,110	2,499.24
Annual total cost.	3,660.36	...	14	98,000	0.357
Annual cost per hour.	0.523	...	15	105,000	0.357

(Table continued top of next column)

of determining Diesel-electric repair costs was not used.

All available traction repair costs given by the A. A. R. and the American Institute of Electrical Engineers, as well as the data on stationary power plants given by the American Society of Mechanical Engineers, were then reviewed in connection with the establishment of the Diesel costs. However, before this repair study was completed, the Northampton & Bath acquired an 800-hp., 116-ton double-power-plant Diesel-electric locomotive and operated it through the first mechanical overhaul period. This locomotive is equipped with two 9-in.

Table II — Estimated Material and Labor Costs for Maintaining Mechanical Equipment on the N. & B. 800-Hp. Diesel-Electric Locomotive*

	Hours at end of period	Material	Labor	Average cost per hour
Year		hours	68 cents per hour	Total
1	7,000	\$463	848	\$1,039.64
2	14,000	483	882	1,082.76
3	21,000	1,045	1,817	1,235.56
4	28,000	503	935	2,280.56
5	35,000	718	1,164	3,124.00
6	42,000	1,065	1,883	2,345.44
7	49,000	463	947	1,106.96
8	56,000	503	1,001	1,183.68
9	63,000	1,645	2,175	1,479.00
10	70,000	798	1,318	1,694.24
11	77,000	463	1,013	1,151.84
12	84,000	1,110	2,043	2,499.24
13	91,000	463	1,046	1,174.28
14	98,000	483	1,079	1,216.72
15	105,000	1,300	2,265	2,840.20
16	112,000	503	1,133	1,273.44
17	119,000	463	1,112	1,219.16
18	126,000	1,665	2,340	3,256.20
19	133,000	463	1,145	1,241.60
20	140,000	818	1,504	1,840.72
21	147,000	1,045	2,114	2,482.52
22	154,000	483	1,211	1,306.48
23	161,000	463	1,194	1,274.92
24	168,000	1,110	2,241	2,633.88
25	175,000	463	1,244	1,308.92

* Based on a 7,000-hr. year.

by 12-in., four-cycle, 400-hp. engines which operate at 900 r.p.m. In order to obtain a comprehensive picture of completely Dieselized operation, a 400-hp. single-power-plant unit with similar Diesel equipment was leased by the road. The Diesel engine and electric equipment of this unit was later overhauled by the company

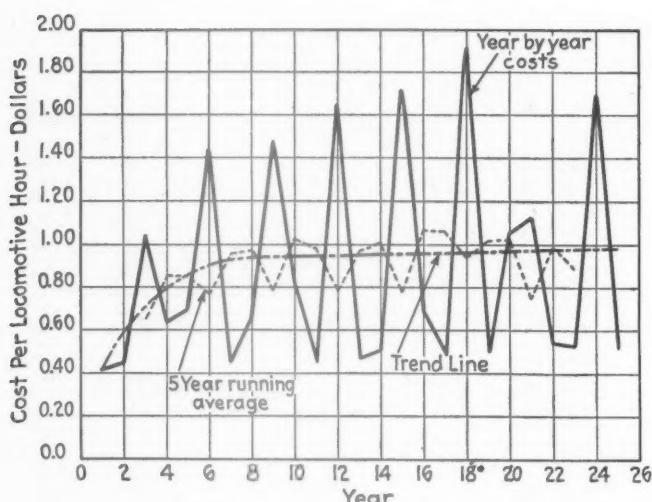


Fig. 4—Average repair cost for the entire locomotive

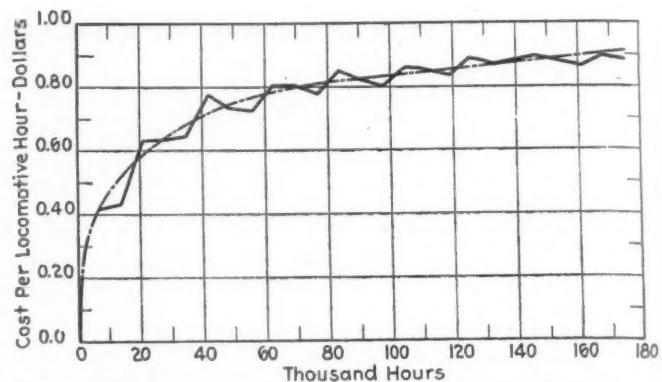


Fig. 5—Cumulative repair cost per locomotive hour for the 800-hp. N. & B. Diesel-electric locomotive

forces before being placed in service. Careful records of material, labor, maintenance, and other expense items were kept for both units throughout their entire operating period. Wear of parts (and thus their service life) was recorded, and all other pertinent data were preserved.

Table III—Estimated Material and Labor Costs for Maintaining Electrical Equipment on the N. & B. 800-Hp. Diesel-Electric Locomotive*

Year	Hours at end of period	Material	Labor hours	Labor at 68 cents per hour	Total	Average cost per hour
1	7,000	\$353	535	\$363.80	\$716.80	\$0.102
2	14,000	353	547	371.96	724.96	0.104
3	21,000	773	839	570.52	1,343.52	0.192
4	28,000	1,003	621	422.28	1,425.28	0.204
5	35,000	353	583	396.44	749.44	0.107
6	42,000	2,293	851	578.68	2,871.68	0.410
7	49,000	353	607	412.76	765.76	0.109
8	56,000	1,003	669	454.92	1,457.92	0.208
9	63,000	873	931	633.08	1,506.08	0.215
10	70,000	728	643	437.24	1,165.24	0.166
11	77,000	353	655	445.40	798.40	0.114
12	84,000	2,943	973	661.64	3,604.64	0.515
13	91,000	353	679	461.72	814.72	0.116
14	98,000	353	691	469.88	822.88	0.118
15	105,000	773	983	668.44	1,441.44	0.206
16	112,000	1,003	765	520.20	1,523.20	0.218
17	119,000	353	727	494.36	847.36	0.121
18	126,000	2,393	1,015	690.20	3,083.20	0.440
19	133,000	353	751	510.68	863.68	0.123
20	140,000	1,378	813	552.84	1,930.84	0.276
21	147,000	773	1,055	717.40	1,490.40	0.213
22	154,000	353	787	535.16	888.16	0.127
23	161,000	353	799	543.32	896.32	0.128
24	168,000	2,943	1,117	759.56	3,702.56	0.529
25	175,000	353	823	559.64	912.64	0.130
				23,115	19,459	0.208
				36,347.12		
					42,044	
					28,589.92	
						74,745.92

* Based on a 7,000-hr. year.

Table IV—Estimated Material and Labor Costs for Maintaining Diesel-Engine Equipment on the N. & B. 800-Hp. Locomotive*

Year	Hours at end of period	Material	Labor hours	Labor at 68 cents per hour	Total	Average cost per hour
1	7,000	\$310	1,272	\$864.96	\$1,174.96	\$0.168
2	14,000	430	1,293	879.24	1,309.24	0.187
3	21,000	2,465	1,638	1,113.84	3,678.84	0.511
4	28,000	980	1,375	935.00	1,915.00	0.274
5	35,000	1,572	1,536	1,044.48	2,616.48	0.374
6	42,000	3,655	1,751	1,190.68	4,845.68	0.692
7	49,000	360	1,398	950.64	1,310.64	0.187
8	56,000	980	1,459	992.12	1,972.12	0.282
9	63,000	4,475	1,850	1,258.00	5,733.00	0.819
10	70,000	1,806	1,651	1,122.68	2,928.68	0.418
11	77,000	310	1,482	1,007.76	3,117.76	0.188
12	84,000	4,205	1,917	1,303.56	5,508.56	0.787
13	91,000	310	1,524	1,036.32	1,346.32	0.192
14	98,000	480	1,545	1,050.60	1,530.60	0.219
15	105,000	6,427	2,070	1,407.60	7,834.60	1.119
16	112,000	980	1,627	1,106.36	2,086.36	0.298
17	119,000	310	1,608	1,093.44	1,403.44	0.200
18	126,000	5,665	2,089	1,420.52	7,085.52	1.012
19	133,000	310	1,650	1,122.00	1,432.00	0.205
20	140,000	2,356	1,901	1,292.68	3,648.68	0.521
21	147,000	2,515	2,016	1,370.88	3,885.88	0.555
22	154,000	430	1,713	1,164.84	1,594.84	0.228
23	161,000	310	1,734	1,179.12	1,489.12	0.213
24	168,000	4,205	2,169	1,474.92	5,679.92	0.811
25	175,000	310	1,776	1,207.68	1,517.68	0.217
		46,156			28,589.92	
						74,745.92

* Based on a 7,000-hr. year.

Table V—Summary of Estimated Material and Labor Costs for Maintenance of Mechanical, Electrical, and Diesel-Engine Equipment on the N. & B. 800-Hp. Locomotive*

Year	Hours at end of period	Material	Labor hours	Labor at 68 cents per hour	Total	Average cost per hour	Cumulative cost	
							Total	Average per hour
1	7,000	\$1,126	2,655	\$1,805.40	\$2,231.40	\$0.419	\$2,931.40	\$0.419
2	14,000	1,266	2,722	1,850.96	3,116.96	0.445	6,048.36	0.432
3	21,000	4,283	4,294	2,919.92	7,202.92	1.029	13,251.28	0.631
4	28,000	2,486	2,931	1,993.08	4,479.08	0.640	17,730.36	0.633
5	35,000	2,643	3,283	2,232.44	4,875.44	0.696	22,605.80	0.646
6	42,000	7,013	4,485	3,049.80	10,062.80	1.438	32,668.60	0.778
7	49,000	1,176	2,952	2,007.36	3,183.36	0.455	35,851.96	0.732
8	56,000	2,486	3,129	2,127.72	4,613.72	0.659	40,465.68	0.723
9	63,000	6,993	4,956	3,370.08	10,363.08	1.480	50,828.76	0.807
10	70,000	3,332	3,612	2,456.16	5,788.16	0.827	56,616.92	0.809
11	77,000	1,126	3,150	2,142.00	3,268.00	0.487	59,884.92	0.778
12	84,000	8,258	4,933	3,354.44	11,612.44	1.659	71,497.36	0.851
13	91,000	1,126	3,249	2,209.32	3,335.32	0.476	74,852.68	0.822
14	98,000	1,316	3,315	2,254.20	3,570.20	0.510	78,402.88	0.800
15	105,000	8,500	5,318	3,616.24	12,116.24	1.731	90,519.12	0.862
16	112,000	2,486	3,525	2,397.00	4,883.00	0.698	95,402.12	0.852
17	119,000	1,126	3,447	2,343.96	3,469.96	0.496	98,872.08	0.831
18	126,000	9,723	5,444	3,701.92	13,424.92	1.918	112,297.00	0.891
19	133,000	1,126	3,546	2,411.28	3,537.28	0.505	115,834.28	0.871
20	140,000	4,552	4,218	2,868.24	7,420.24	1.060	123,254.52	0.880
21	147,000	4,333	5,185	3,525.80	7,858.80	1.123	131,113.32	0.892
22	154,000	1,266	3,711	2,523.48	3,789.48	0.541	134,902.80	0.876
23	161,000	1,126	3,727	2,534.36	3,660.36	0.523	138,563.16	0.861
24	168,000	8,258	5,527	3,758.36	12,016.36	1.717	150,579.62	0.896
25	175,000	1,126	3,843	2,613.24	3,739.24	0.534	154,318.76	0.882
		88,252	97,157	66,066.76	154,318.76	0.882		

* Based on a 7,000-hr. year.

The determination of repair cost trends was made by analyzing (1) the data collected by the Northampton & Bath on its two Diesel-electric units, (2) Diesel operating costs as furnished by other railroads, and (3) the cost of operating and maintaining steam locomotives. The analysis of these data resulted in a fairly accurate determination of the life of the various parts of the trucks, underframe, cabs, electrical equipment, Diesels and auxiliaries, as well as the labor hours required for replacing worn parts. The cost of maintaining the 800-hp. Diesel-electric locomotive over a twenty-five year period was then tabulated. These costs are given in Tables I to V, inclusive.

The data in Table I gives service hours expected from the various parts of the mechanical, electrical and Diesel equipment; the year in which the parts are expected to be replaced; and the labor hours required for replacing worn parts. In some cases it will be noted that hours of labor are omitted. In these instances the labor charge is taken care of either in disassembly and assembly of the individual units, or by the annual labor charge. It will be seen from Table I that it has been assumed the locomotive will have an average life of twenty-five years, and that it will give 7,000 hr. of service per year, which is equivalent to an availability of 80 per cent. The table also includes the total hours of labor,

cost of labor at a rate of 68 cents per hour, and the total cost of labor and material for each year.

Tables II, III, and IV give summaries of the year-by-year cost for maintaining the mechanical, electrical, and Diesel equipment, respectively. These tables also show the total cost per year and the yearly average cost per hour for maintaining the locomotive. Table V is a grand summary which shows the average repair cost per hour for the entire locomotive as well as the total cumulative cost and average cumulative cost per year.

Figs. 1 to 5, inclusive, show the annual cost per locomotive hour of maintaining the mechanical, electrical, and Diesel equipment, the annual cost per locomotive hour of maintaining the entire locomotive, and the yearly accumulative repair costs. Trend lines and five-year running averages are also shown in these figures. Fig. 1 is plotted from Table II, Fig. 2 is plotted from Table III, and Fig. 3 is plotted from Table IV, showing the average repair costs per locomotive hour over the twenty-five year period for electrical, mechanical and Diesel equipment, respectively. Fig. 4, plotted from the values given in the seventh column of Table V, shows the average repair costs per locomotive hour for the entire locomotive over the twenty-five year period. Fig. 5, showing cumulative repair costs for this period, is plotted from values in the last column of Table V.

A.A.R. Passenger-Car

Air-Conditioning Report

ON December 20, 1935, the Board of Directors of the Association of American Railroads authorized the Division of Equipment Research to undertake an extensive investigation of the air-conditioning of railroad passenger cars. The investigation was undertaken because of the magnitude of the investment in railroad air-conditioned equipment and the necessity of securing maximum returns from equipment installed now or to be installed in the future. Table I shows the extent of the investment in air-conditioned cars and terminal facilities owned by the railroads in the United States and Canada as of March 1, 1935. On October 1, 1936, there were 8,031 air-conditioned passenger cars in the United States and Canada, of which 3,907 were owned by the railroads and 4,124 were owned by the Pullman-Standard Car Manufacturing Company.

To accomplish the objectives of the investigation, the project was conceived as consisting of the following steps: (1) Survey of the performance of equipment in service; (2) determination of the efficiency of air-conditioning systems; (3) determination of the mechanical efficiency of the drive mechanisms; (4) study of the air requirements, treatment, diffusion, and related matters; (5) determination of the cost of air-conditioning per 1,000 car-miles; and (6) study of the factors relating to passenger comfort. During the course of the investigation, road tests were conducted on 594 passenger cars of which 434 were air-conditioned cars owned by railroads, 10 were railroad-owned cars not air-conditioned, and 120 were air-conditioned cars owned by the Pullman Company. The report submitted on this work is called a "Summary Report on Air-Conditioning of Railroad Cars," and deals entirely with the railroad-owned cars. A report on the Pullman cars is to be released at a later date. In addition to the summary report

and the report on the Pullman cars, the A.A.R. will later release an engineering report to meet the needs of air-conditioning engineers and operating personnel, and reports to the individual railroads which assisted in conducting the investigation. These latter reports will give in detail the results obtained by testing the equipment of the respective railroads. The scope of the work done in securing the information for preparing these reports is presented in Table II.

Systems Tested and Results

It is seen from Table II that 15 air-conditioning systems were tested in the laboratory of which 12 were mechanical-compression units. The remaining three

Table I—Net Charge to Investment Account—Air Conditioning Equipment—2,653 Cars Owned by 45 Railroads in U. S. and Canada, as of March 1, 1936

	Number of units	Total amount
Mechanical compression:		
Electro-mechanical drive	702	\$3,922,245.46
Direct-mechanical drive (Pullman)	423	3,481,597.66
Internal combustion engine drive (Waukesha)	1	3,729.76
Head-end power drive (articulated trains)	20	66,275.58
Total	1,146	\$7,473,848.46
Steam ejector	464	3,396,297.02
Ice activated	1,043	3,216,888.41
Total	2,653	\$14,087,033.89
Additional facilities (terminal) .....	...	1,157,131.54 (a)
Grand Total	2,653	\$15,244,165.43

(a) Values for two railroads not reported.

were steam-ejector, ice-activated, and evaporative-cooling units. During the tests of these units the inlet air to the cooling coil (the evaporator of the mechanical-compression systems) was maintained at 80 deg. F., and the relative humidity was maintained at 50 per cent

Table II—Scope of the A.A.R. Air-Conditioning Investigation

Number of air-conditioning systems tested in laboratory...	15
Mechanical compression	12
Steam ejector	1
Ice activated	1
Evaporative cooling	1
Number of drive mechanisms tested in laboratory...	6
Belt	1
Gear	2
Belt and gear	2
Friction	1
Number of air-conditioned cars tested in hot room...	14
Mechanical compression	7
Steam ejector	1
Ice activated	6
Number of railroads that conducted road tests...	31
Number of passenger cars on which road tests were conducted...	594
Railroad-owned air-conditioned cars	434
Railroad-owned non-air-conditioned cars	40
Pullman air-conditioned sleepers	120
Percentage of railroad-owned air-conditioned cars tested to total number of railroad-owned air-conditioned cars as of March 1, 1936	18
Approximate number of hours of road testing	5,200
Approximate number of miles of road testing	240,000
Number of passengers who submitted comments on conditions in air-conditioned cars while tests were being made	5,453
Approximate number of data readings recorded for all laboratory and road tests	250,000
Approximate number of calculations made from recorded data	85,000
The analysis of costs is based upon an experience record of 1,608 cars for 1935 with a total car mileage of....	178,259,768

in order to subject each of the systems to uniform test conditions.

Mechanical-Compression Systems—The performance of nine of the 12 mechanical-compression systems is shown in Table III. At a condenser air-temperature of 90 deg. F. all but two of the mechanical-compression systems tested delivered their rated capacity. The Frigidaire failed to produce its rated tonnage by 0.39

steam per hour. The range for the one steam system tested was 0.58 to 0.64 kw. per ton, and 30.5 to 34.6 lb. of steam per hr. per ton of refrigeration, exclusive of the amount of condensate which ordinarily occurs in a train line. The electrical power required was approximately one third of that required by the most efficient mechanical systems. Throughout the entire range of condenser air temperatures at the zero resistance pressure, the capacity of the steam-ejector system tested remained constant, and its rated capacity at the refrigeration unit was obtained. The system tested consisted of a Carrier steam ejector, Safety pumps and motors, a Carrier condenser, and Aerofin cooling coils (Carrier-Safety design). Its weight was 3,698 lb.

Ice-Activated System—The ice-activated system tested consumed 0.17 to 0.21 kw. of electric power per ton of refrigeration and 76.7 to 78.3 lb. of ice per hr. per ton of refrigeration. The system delivered its rated capacity at a cold-water temperature of 41 deg. F. The system tested consisted of an American Car & Foundry bunker and cooling coils, a Worthington pump, and a Master motor. Its weight was 3,845 lb. with the bunker empty.

Evaporative-Cooling System—The Fleischer evaporative cooling system produces no refrigeration. The system has limited possibilities with respect to cooling railroad passenger cars. This system will produce comfort conditions only in those sections of the country where low wet-bulb temperatures prevail, or where only a slight temperature reduction is required. When used as a supplement to a refrigerating system it operates only as an air washer. The Fleischer system consumes 1.22 kw. of electric power. The system tested consisted

Table III—Power Requirements of 12 Mechanical Compression Air-Conditioning Systems Determined by Laboratory Tests

System	Description						Kilowatts per ton of refrigeration at air resistance pressures in inches of water		Wt. in lb.
	Compressor	Condenser	Evaporator	Compressor Motor	Expansion valve	in. of water	kw.		
1. Airtemp-York (5-ton)...	York	York	York	Westinghouse	Detroit Lubricator	Zero	0.35		2,795
2. Carrier-Safety	Safety	Aerofin (a)	Aerofin (a)	Safety	Detroit Lubricator	1.35	1.43		3,030
3. Trane	Lipman	Trane evaporative	Trane	Wagner	Alco Constant Pressure	1.48	1.57		3,660
4. Airtemp-York (6-ton)...	York	York-evaporative (b)	York	Westinghouse	Detroit Lubricator	1.59	1.65		2,795
5. Airtemp-York (7-ton)...	York	York evaporative	York	Westinghouse	Detroit Lubricator	1.62	1.66		2,795
6. B&O-York	York	York evaporative	York	Fairbanks-Morse	Detroit Lubricator	1.70	1.75		2,396
7. General Electric	General Electric	Trane (c)	Trane (c)	General Electric	Detroit Lubricator	1.83	1.90		3,081
8. Frigidaire	Frigidaire	Frigidaire	Frigidaire	General Electric	Frigidaire	1.96	2.03		2,375
9. Waukesha-Sturtevant supercondenser	Ingersoll-Rand	Trane with Super-condenser	Sturtevant	Waukesha internal-combustion engine	Alco Thermostatic				4,050
10. Baldwin-Southwark	De La Vergne			Century		2.48	2.78	3,134 (Two units)	
11. Waukesha-Sturtevant	Ingersoll-Rand	Trane	Sturtevant	Waukesha internal-combustion engine	Alco Thermostatic			3,450	
12. Waukesha-Trane	Ingersoll-Rand	Trane	Trane	Waukesha Internal-combustion engine	Detroit Lubricator			3,420	
(a) Carrier-Safety design.									
(b) Above 100 deg. Fahrenheit.									
(c) General Electric design.									

ton, and the Waukesha, in the three installations tested, failed by amounts up to 2.28 tons. The steam-ejector, ice-activated, and evaporative-cooling systems were not included in Table III because their power requirements are of a different character and order. On the basis of power consumption these systems cannot be compared directly with the mechanical-compression systems. The only way in which such a comparison may be made is on a cost basis; this will be discussed later.

Steam-Ejector System—The steam system requires both electrical power and steam, therefore, the power consumed is expressed in kilowatts and in pounds of

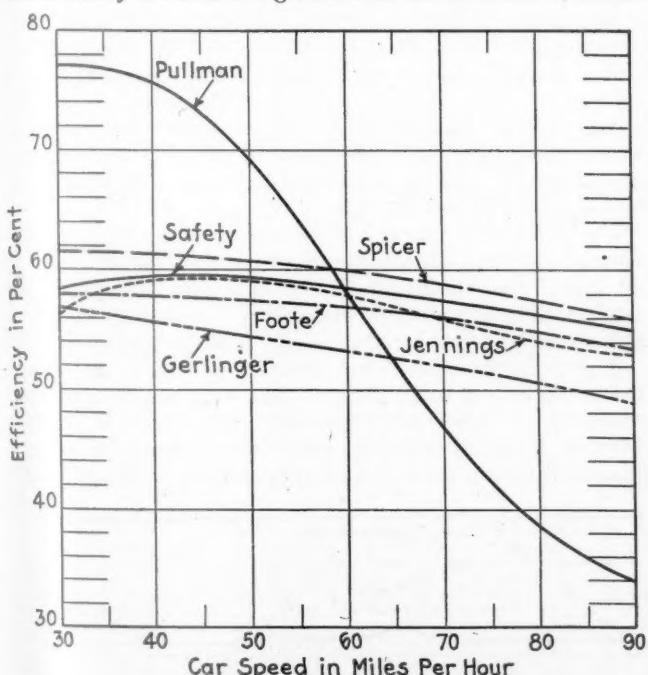
of an Air & Refrigeration Corporation evaporative cooler, a Worthington pump, a Master motor, and a Clarage circulating fan. Its weight was 612 lb.

Drive Mechanisms

The mechanical efficiency of six types of drive mechanisms through which power is transmitted from the car axle to the cooling equipment was determined during the tests. The mechanical efficiency of the drives tested (including drive, generator, and compressor motor) were obtained, as shown in one of the figures, for equivalent car speeds between 30 and 90 m.p.h.

The drives tested were (1) the Spicer Railway Car hypoid gear drive for a 20-kw. generator; (2) a Foote Brothers spur-and-bevel gear for a 10-kw. generator; (3) Safety Car Heating & Lighting Company V-belt and bevel gear for a 20-kw. generator; (4) a Pullman drive, including speed control for operating the air-conditioning compressor; (5) a Jennings V-belt drive for a 10-kw. generator; and (6) a Gerlinger friction drive for a 5-kw. generator. Loads used during the tests ranged from zero to 36 hp. for the 20-kw. drives, from zero to 18 hp. for the 10-kw. drives, and from zero to 10-hp. for the 5-kw. drive. The Pullman direct drive was tested at constant torques of 51 and 71 ft.-lb., with a speed-control setting of 42 m.p.h. The torque of 71 ft.-lb. is that required to operate an air-conditioning system at full capacity.

In view of the trend toward higher train speeds, the comparison of the efficiency of the Pullman drive with the efficiencies of the other drives is significant. The Pullman drive is normally adjusted so that slippage in the speed control starts at a train speed of about 42 m.p.h. Below that speed, the compressor is operated at reduced speed and, consequently, at reduced capacity. Adjustment of the speed control, together with changes in the gear ratio, will make it possible to increase the speed at which slippage starts. In some cases the speed-control setting has been advanced from 42 to 55 m.p.h. for high-speed trains in order to improve the efficiency in the upper range of speeds. This means some sacrifice in the cooling capacity at speeds below 55 m.p.h. Some railroads use a heavy oil and a high level of oil with the Pullman



Efficiencies of car-axle drives, including generator and compressor motor for electro-mechanical drives and speed control (Set for 42 m.p.h. for Pullman direct drive)

drive. A lighter oil and a lower oil level would increase the mechanical efficiency somewhat.

The Gerlinger drive may be disregarded for air-conditioning purposes where mechanical-compression systems are used, because of insufficient capacity.

With belt drives the cost due to the loss of belts may be appreciable. This cost on one railroad, with fifty-nine cars and over a period of 32 months, was approximately \$6,000. Belt losses and breakages are due to many causes, among which are flying ballast and the accumulation of snow and ice on the pulleys. One railroad increased belt life from 29,000 to 44,000 miles by

Table IV—Total Cost Per 1,000 Car-Miles for Four Types of Air-Conditioning Systems for Railroad Passenger Cars for an Average Cooling Season of Five Months, an Average Train Speed of 50 M.P.H., and an Average Car Mileage of 150,000 Miles Per Year, Based on Experience of 16 Railroads in 1935

	Electro-mechanical	Direct-mechanical	Steam ejector	Ice activated
GROSS INSTALLATION COST				
(a) Charged to investment account (gross)	\$6,110.00	\$8,493.00	\$8,242.00	\$3,587.00
(b) Charged to operating expense account	374.00	22.00	233.00	395.00
Total	\$6,484.00	\$8,515.00	\$8,475.00	\$3,982.00
ANNUAL FIXED CHARGES				
(a) Investment: Depreciation at 12.5 per cent \$763.75	\$1,061.63	\$1,030.25	\$448.38	215.22
Interest at 6 per cent 366.60	509.58	494.52		
Taxes and Ins. at 1.5 per cent 91.65	127.39	123.63	53.80	
Total	\$1,222.00	\$1,698.60	\$1,648.40	\$717.40
(b) Operating expense: Allocated over life of equipment at 12½ per cent 46.75	2.75	29.13	49.38	
Total annual fixed charge	\$1,268.75	\$1,701.35	\$1,677.53	\$766.78
TOTAL COST PER 1,000 CAR-MILES				
(a) Fixed charges	\$8.45	\$11.35	\$11.18	\$5.11
(b) Operation cost .....	.99	.93	1.02	.529
(c) Maintenance cost	3.33	2.33	2.15	.97
Total	\$12.77	\$14.61	\$14.35	\$11.37

increasing the diameter of the armature pulley from 8 in. to 10 in., and using a 5-in. six-ply rubber belt. A gear-drive mileage of 350,000 has been reported with evidence of only ordinary wear. The outstanding record reported was for a combination belt-and-gear drive which has been in service five years without failure. The mileage to September 1, 1936, was 1,000,000.

Cost Per 1,000 Car Miles

The total cost of installing four different types of air-conditioning systems is shown in Table IV, together with the cost per 1,000 car-miles. The figures shown in this table were derived from those submitted by 16 railroads, and are based on an average cooling season of five months, an average car mileage of 150,000 miles per year, and an average train speed of 50 m.p.h. The cost

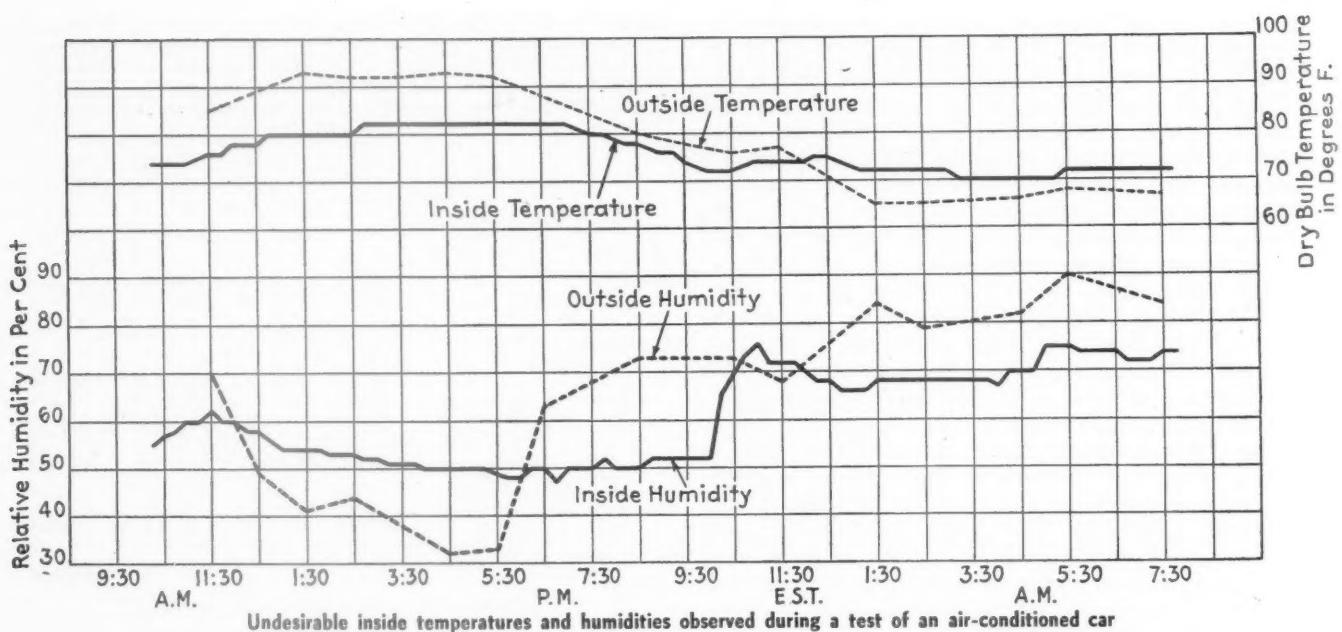
Table V—Maintenance Cost of Air Conditioning—16 Railroads in 1935

	Number of units	Number of car-miles	Maintenance cost	
			Amount	Cost per 1,000 car-miles
Electro-mechanical	391	35,557,629	\$118,538.22	\$3.33
Direct-mechanical (Pullman)	312	42,926,532	100,043.03	2.33
Steam ejector	223	28,434,558	61,026.23	2.15
Ice activated	527	48,771,407	47,139.34	.97

of maintenance, for 1935, was reported by the 16 railroads as shown in Table V.

Comparative total costs per 1,000 car-miles of four different methods of air-conditioning railroad passenger cars for cooling seasons of three and ten months, for train speeds of 30, 50, 70, and 90 m.p.h., and for car mileages ranging from 50,000 to 250,000 are shown in Table VI. The influence of car mileage, train speed, and length of cooling season upon the cost per 1,000 car-miles for each of the four air-conditioning systems can be readily observed from this table.

From an analysis of such figures as given in Table VI it is evident that the economics of air-conditioning, from an operating standpoint, is affected by a number of factors, namely, (a) the length of the cooling period and



the atmospheric conditions prevailing during that period, (b) the average speed in miles per hour, and (c) the total number of car-miles per year. Because of this, a categorical statement cannot be made as to which system is the best from the standpoint of economics. In each case, the selection has to be made on the basis of the prevailing operating circumstances to be confronted. Table VI has been prepared so that the total cost per 1,000 car-miles may be determined in accordance with the character of the variables to be confronted. There is presented in Table VII a number of examples to illustrate the use of Table VI. The costs shown in Table VII are based on the average speed in miles per hour and the car-miles per year which approximate the average scheduled speeds and car-miles of typical trains in the several regions. The several regions are listed in accordance with approximate present practice with respect to the length of the cooling season. There is, of course, no sharp boundary line concerning these matters.

Economics of Air Conditioning

The foregoing cost figures bring forward the influence of the cost of installation, and therefore, of fixed charges upon the total cost of operation.

The fixed charges for an ice system are the lowest of all systems. During cooling seasons of three and five months, the fixed charges of the ice system influence the total cost more than does the cost of operation; hence, the total cost for the ice system is the lowest. However, with a cooling season of eight or ten months, the cost of operation of the ice system influences the total cost more than do fixed charges. This being the case, the ice system becomes more expensive than the electro-mechanical system. The fixed charges for the electro-mechanical system are less than all other systems, except ice. For this reason, the total cost of operation of the electro-mechanical system for cooling seasons of eight and ten months is the lowest of all the systems.

The foregoing discussion of the ice and electro-mechanical systems focuses attention upon the importance of the gross cost of installation. It is the gross cost of installation which must be reduced if a material reduction in the total cost per 1,000 car-miles is to be accomplished.

It is recognized that in selecting an air-conditioning system there are other factors than cost which must be considered. These are reliability, adequacy of results obtained, terminal facilities, and other matters. However, gross installation costs and total operating costs per 1,000

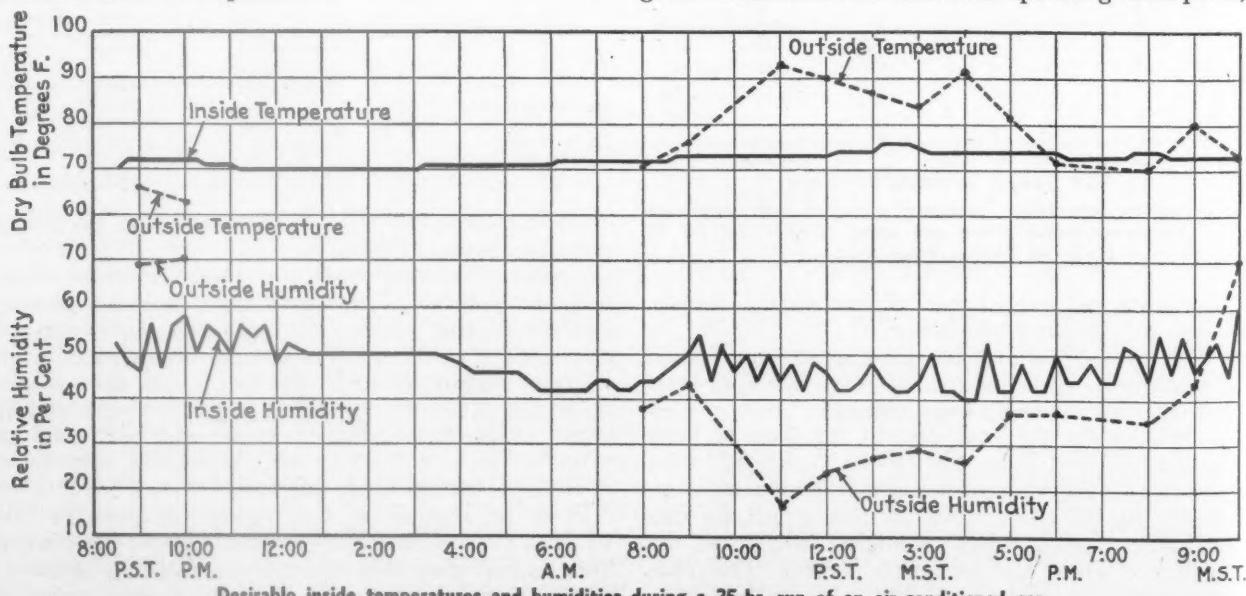


Table VI—Comparative Total Cost Per 1,000 Car-Miles of Four Different Methods of Air Conditioning Railroad Passenger Cars for Cooling Seasons of Three and Ten Months

	Cost per 1,000 car-miles on the basis of the following car-miles per year:				
	50,000	100,000	150,000	200,000	250,000
Train speed of 30 m.p.h.:					
Electro-mechanical:					
Three months	\$29.89	\$17.20	\$12.96	\$10.85	\$9.58
Ten months	30.73	18.04	13.80	11.69	10.42
Direct-mechanical:					
Three months	37.47	20.46	14.80	11.95	10.25
Ten months	38.09	21.08	15.42	12.57	10.87
Steam ejector:					
Three months	36.95	20.18	14.58	11.79	10.10
Ten months	37.57	20.80	15.20	12.41	10.72
Ice activated:					
Three months	21.74	14.08	11.52	10.25	9.49
Ten months	32.81	25.15	22.59	21.32	20.55
Train speed of 50 m.p.h.:					
Electro-mechanical:					
Three months	29.56	16.87	12.63	10.52	9.25
Ten months	30.07	17.28	13.14	11.03	9.76
Direct-mechanical:					
Three months	37.16	20.15	14.49	11.64	9.94
Ten months	37.58	20.57	14.91	12.06	10.36
Steam ejectors:					
Three months	36.62	19.58	14.25	11.46	9.77
Ten months	36.99	20.22	14.62	11.83	10.14
Ice activated:					
Three months	19.70	12.04	9.48	8.21	7.44
Ten months	27.17	19.51	16.95	15.68	14.91
Train speed of 70 m.p.h.:					
Electro-mechanical:					
Three months	29.50	16.81	12.57	10.46	9.19
Ten months	29.88	17.19	12.95	10.84	9.57
Direct-mechanical:					
Three months	37.17	20.16	14.50	11.65	9.95
Ten months	37.64	20.63	14.97	12.12	10.42
Steam ejector:					
Three months	36.57	19.80	14.20	11.41	9.72
Ten months	36.84	20.07	14.47	11.68	9.99
Ice activated:					
Three months	18.88	11.22	8.66	7.39	6.62
Ten months	23.62	15.96	13.40	12.13	11.36
Train speed of 90 m.p.h.:					
Electro-mechanical:					
Three months	29.63	16.94	12.70	10.59	9.32
Ten months	29.94	17.25	13.01	10.90	9.63
Direct-mechanical:					
Three months	37.31	20.30	14.64	11.79	10.09
Ten months	37.83	20.82	15.16	12.31	10.61
Steam ejector:					
Three months	36.73	19.96	14.36	11.57	9.88
Ten months	36.94	20.17	14.57	11.78	10.09
Ice activated:					
Three months	18.57	10.91	8.35	7.08	6.31
Ten months	22.26	14.60	12.04	10.77	10.00

EDITOR'S NOTE: This table is a composite of two tables found in the A.A.R. summary report. It has been compiled to show the spread in cost per 1,000 car-miles of the four air-conditioning systems between seasons of three and ten months duration. The A.A.R. summary report also contained tables showing the cost per 1,000 car miles for seasons of five and eight months.

car-miles are dependable units of measurement and, hence, due weight should be accorded them. This is especially true in the light of the large potential investment confronting the railroads through an increase in the number of cars to be air conditioned. In considering the economics of air conditioning, it must be remembered that the overall cost, efficiency, and economy of any air-conditioning system may be markedly affected by the cost, efficiency, and economy factors associated with each element of the system. For instance, a given air-conditioning system may be composed of a combination of parts such that the gross installation cost, efficiency, and economy of the system will be all that could be expected. If a substitution is made for some parts, which substituted parts do not rank equally with those replaced, it may be found that the overall cost, efficiency, and econ-

Table VII—Average Cost Per 1,000 Car-Miles of Four Different Methods of Air Conditioning Passenger Cars for Cooling Seasons in Various Locations of the United States and Canada*

	Average Cost per 1,000 car-miles for seasons of the following lengths:			
	3 months ¹	5 months ²	8 months ³	10 months ⁴
Electro-mechanical	\$12.63	\$12.77	\$12.99	\$13.44
Direct-mechanical	14.49	14.65	14.78	14.91
Steam ejector	14.25	14.35	14.51	14.62
Ice activated	9.48	11.37	14.22	16.95

* Values in this table are based on the average speed in miles per hour and the car-miles per year which approximate the averaged scheduled speeds and car-miles of typical trains in the several regions listed as follows:

¹ New England, Great Lakes, and Northwestern.

² Great Lakes, Central Eastern, Pocahontas, and Northwestern.

³ Pocahontas, Southwestern, and Central Western.

⁴ Southern, Southwestern, and Central Western. These regions are listed in accordance with approximate present practice with respect to cooling seasons.

EDITOR'S NOTE: This table is not found in the A.A.R. summary report, but has been compiled from data in the report to facilitate presentation.

omy are much less favorable than they were in the first case. This means that in selecting and purchasing an air-conditioning system, the purchase price, efficiency, and economy of each part should be considered carefully. Otherwise, there may be no assurance of the merits and the reasonableness of the cost of the system selected and purchased.

The Waukesha system was not included in the foregoing economic analysis because only one installation was made prior to 1936. An effort will be made to obtain the necessary information concerning the 1936 installations upon which to base an analysis.

Factors Relating to Passenger Comforts

Variations in conditions in 302 air-conditioned cars were determined from data gathered by 20 railroads during regular service runs made from August 1 to September 15, 1936. It was found that a temperature between 72 and 76 deg. F. has been selected as most desirable to maintain relative humidity with the range of 30 to 60 per cent., and that a relative humidity of 70 per cent

Table VIII—Analysis of the 4.4 Per Cent of Passenger Comments Which Were Unfavorable

	Number of comments	Percentage of total comments
Much too warm	75	2.7
Slightly too warm	505	17.9
Much too cool	51	1.8
Slightly too cool	530	18.7
Clammy	113	4.0
Stuffy	240	8.5
Drafty	197	7.0
Noisy	196	6.9
Too cool upon entering	205	7.3
Objectionable odor	140	5.0
Excessive tobacco smoke	135	4.8
Too much heat from sunshine through windows	435	15.4
Total number of unfavorable comments..	2,822	100.0

is undesirable. The prevailing thought appears to be that the desirable air movement within an air-conditioned car is 25 to 75 ft. per min., and that the maximum permissible is 120 ft. per min.

The average volume of fresh air in cubic feet per minute delivered into the cars through the cooling system during the tests was determined for each of 114 runs. The average for the runs varied as follows: Less than 200 cu. ft. per min. for 10 runs; from 200 to 399 cu. ft. per min. for 43 runs, from 400 to 599 cu. ft. per min. for 41 runs; from 600 to 799 cu. ft. per min. for 16 runs; and 800 cu. ft. per min. and over for 4 runs. Typical conditions of inside temperature, outside temperature, and humidity in air-conditioned cars are shown in two of the figures.

Temperature and Humidity Control—The process of



Car equipped with instruments for test of air-conditioning system. Light bulbs are used to deliver sensible heat. Insulated water pots in the aisles are used to deliver latent heat. Thermometers are located at duct outlets at the car roof. Thermocouples are used to obtain surface temperature of the car. Panel board is shown in the background.

cooling cars, like that of heating, requires some form of temperature control. The optimum comfort in air-conditioned cars will not be attained until the control problem is solved. The solution of the problem will also contribute to a reduction in operating costs. There are three general types of controls: Manual, semiautomatic, and automatic. The latter two are accomplished by various means. These will be discussed at length in the engineering report (this will be submitted at some later date by the A.A.R.). The manual type of control is highly unsatisfactory. If uniform and regular performance is desired, it should not be used. The semiautomatic type is a marked improvement over the full manual, but the human element is associated with it. The elimination of this element is desirable. The automatic types have not been perfected to the degree desired. There is much development work necessary. There are those who feel that a form of modulated temperature control is needed. Such a type of control would automatically maintain within the car a predetermined number of degrees lower temperature than the outside temperature. A successful control of this type would mark a real advance in air conditioning. Temperature control is inseparably associated with humidity control. There is a diversity of opinion as to the need for humidity control. Most authorities agree that some type of humidity control is advisable.

Filters—An important advantage of air conditioning passenger cars is cleanliness. The cleaning is done by passing air through the filters, which are not only important from the viewpoint of cleanliness, but also with respect to odors. The filter problem is indicated by the many different types being used. They are either dry or impregnated with oil of varying viscosity, and are made of spun bronze wool, not coated; series of wire screens of progressive decrease in mesh, oil coated; metal shavings packed in a frame; spun glass; copper sprayed with oil impregnated hair; oiled paper; perforated cardboard coated with oil; and others. They range in price from 65 cents to \$17.00 each. The filter is too important an element with respect to cleanliness, odors, and operation costs to be neglected. There is a real need for a thorough and exhaustive study of the entire filter situation.

Odors—The problem of odors is universal. Some

railroads have had reasonable success in reducing them. Odors result mainly from gas or smoke from the locomotive, tobacco smoke, body odors given off by passengers, improperly maintained toilets, refuse thrown on the floor by passengers and from cooking and garbage in the dining cars. Odors are aggravated by humidity in excess of 60 per cent within the car and by an excessive use of disinfectant. Tobacco smoke, dust, and moisture produce a sour smell in the cooling coils if they are not cleaned often enough. Filters become impregnated with nicotine and grease, and odors result if they are not frequently cleaned or renewed. From the use of oil on the filters, a gummy substance settles in the ducts which absorbs odors from cosmetics, tobacco, garbage, and other material. Deodorants have been used with varying success. The use of ozone has been widely discussed as a purifying agent. Its value is doubtful.

Passenger Reactions and Comments

One phase of the road work was to ascertain the reactions of passengers to the conditions prevailing in the air-conditioned cars. At the time the road engineers were making observations in a car, each passenger was given a card. This card requested the passenger to cooperate in making the study by indicating thereon his reaction to a number of factors, such as temperature, odors, and the like. An analysis of these comments appears in Table VIII.

Dynamic Stresses in Freight-Car Design

(Continued from page 101)

alloy steel or other materials, he knows what further weight reductions can be made, taking into account higher permissible stresses and their corresponding deflections.

He knows how to iron out peak stresses and deflections and how to avoid or cushion the reversal of stresses. He knows how to avoid dynamic, as well as static, stress concentrations. He knows how to make the structure approach unitary action.

He appreciates the fallacy of considering all members of a built-up structure of equal value. The fewer the parts, if the design properly locates them, the lighter and better the structure, i.e., with the above qualifications, the closer we approach the unit structure the better off we are. You can't put a lot of members together by any known method and hope to get results corresponding to the sum total of these members, no matter what materials or methods of construction are used. As just one proof of this, the new A. A. R. center sill is an example of a unit member which has a cross-sectional area of approximately 21 sq. in. This sill, under the same testing conditions, gave a better account of itself and was subjected to higher impact speeds than the built-up riveted A. A. R. center sill, composed of three members having a cross-sectional area of 28 sq. in.

A freight car at rest is only of passing interest; the same may be said of static stresses and deflections; cars must be designed and built for service or dynamic stresses. Take two 50-ton cars, loaded to journal capacity, with one car moving at a rate of six to seven miles an hour and striking the other car at rest. What happens? The car structure must absorb or transmit impact forces for all speeds above this. Did it ever occur to you that a proper car structure might minimize damage to lading?

The reasons for putting so much emphasis on the

necessity of constructing cars to meet the dynamic forces must be evident. Light-weight freight cars are the goal which we are approaching. This means that every pound in a car or truck structure must be there because it is needed, and it must be where it is needed. In the end, using only the required amount and the proper placing of this material means lower first cost to the railroad and an increase in ratio of lading capacity to light or tare weight, with attendant reduction in operating cost, which is the economic urge.

High-Pressure Locomotive Safety Valves

Its FG-10 muffled and FC open pop locomotive safety valves, which were developed to meet the condition of increased evaporating efficiency on high pressure locomotive boilers, are reported by the Ashton Valve Company, Boston, Mass., to have operated successfully for a period of over five years in road tests on locomotives carrying pressures up to 300 lb. sq. in. The valves have operated throughout this period without the necessity of the renewal of any parts.

The general construction principles are the same as the regular Ashton locomotive safety valves, being provided with wide wing guides in the bottom section and a sleeve guide at the top to keep the wing guide in alignment. The springs are guaranteed for five years when used for the pressure for which they are constructed.

The valves, built on the bolted body principle, are provided with pop regulators for adjusting and regulating the pop. These regulators are always accessible, requiring no special wrenches, and function on the same principle as an ordinary globe valve. No rings or sleeves are required for regulating blowback.

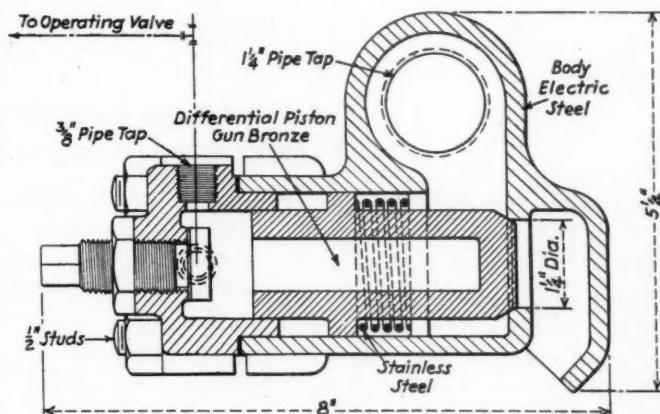
Steam-Operated Cylinder Cock

A steam-operated cylinder cock with a large opening from cylinder to atmosphere, equivalent to the capacity of 1½-in. pipe, has been placed on the market by the T-Z Railway Equipment Company, Chicago. The use of steam instead of air as an operating medium is said

to reduce pressure. When the cab valve is moved to open position, boiler pressure is shut off from the cylinder cock steam chamber and the latter exhausted to the atmosphere, when the cylinder cock will instantly open by the action of cylinder pressure on the differential piston. The cylinder cock also automatically opens by pressure, due to compression, water, etc., above a pre-determined amount, thus eliminating possible damage to cylinder heads and reciprocating parts.

With the cab valve in open position and the main throttle closed, as in the enginehouse, the cylinder cock automatically opens by means of a stainless steel compression spring about the differential piston aided by a slight accumulation of cylinder pressure, thus preventing accidental movement of the locomotive.

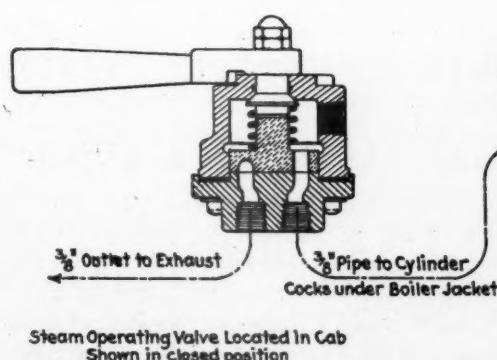
The adjusting screw in the cap permits the cylinder



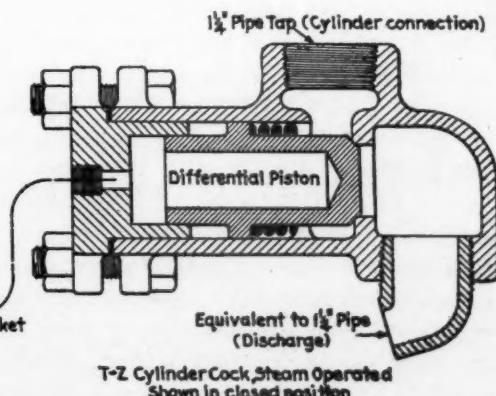
Section through the cylinder cock

cock to be clamped closed in the event of a broken steam pipe thereto, and for testing superheater units and cylinders. Freezing is prevented and cylinder lubrication improved when drifting by providing a slight circulation of live steam about the differential piston which steam passes into the cylinder instead of the atmosphere and therefore cannot impair clear forward vision.

This type of cylinder cock is suitable for right or left application by reversing the 1½-in. pipe plug at the cylinder connection. This plug affords an additional ad-



Sectional views of the T-Z steam-operated cylinder cock and cab operating valve



to make the device more positive and reliable in action and eliminate the possibility of air defects.

The new cylinder cock is controlled both manually and automatically. Manual operation is obtained through a rotary cab-operating valve which, in closed position, admits steam at boiler pressure onto a differential piston which holds each cylinder cock closed against cylinder

vantage, since by its removal, dirt and carbon can be blown from the cylinder without disturbing the cylinder cocks or piping.

The design provides maximum clearance above the rail to reduce the liability of being knocked off by roadway obstruction. It is also applicable to cylinder exhaust channels and receiver pipes of Mallet locomotives.

Seven-Year Summary of Air-Conditioned Cars

Note 1.—Includes lounge-diners, coach-diners, cafe-chairs, cafe-coach, kitchen-coach and buffet cars.

Note 2—Includes lounge-chair, coach-chair and observation-chair cars.
Note 3—Includes lounge and observation-sleepers.
Note 4—Includes 66 cars on which the compensation is defined as

Note 4—Includes 66 cars on which the compressor is driven by a gas engine.

Aspinai

EDITORIALS

Mechanical Engineer Of Distinction

Sir John Aspinall, who died in England, January 19, at the age of 85, means little, if anything, to the present generation of railway mechanical executives in this country, and yet in Great Britain his ability and achievements in that department are highly regarded, despite the fact that he was promoted to the position of general manager of the Lancashire & Yorkshire as far back as 1899. He was chief mechanical engineer (head of the mechanical department) on that road from 1886 to 1899, assuming that office at the age of 35.

It was while in that position that he built the great shops at Horwich. The first new locomotive was completed in 1889 and in the ten years which followed, 667 locomotives of various types were built under his direction. These included his Atlantics, among the earliest of that type to be constructed.

As general manager of the road he made a splendid reputation as an administrator, but he never lost interest in engineering problems. It was under his direction that the electrification program was started, the completion of the electrification of the Liverpool & Southport in 1904 marking the first "main line" electrification in the United Kingdom.

Sir John retired from the general managership in 1919. He was knighted in 1917. Many years ago he was made an honorary member of the council of the British Institution of Mechanical Engineers—a signal and unusual honor—and in that capacity regularly attended all council meetings. He was recently awarded the first International James Watt Medal; unfortunately he died only a few days before the actual presentation was to be made.

He was indeed a grand old man and apparently was held in much the same high regard and affection among the engineers of England as is Ambrose Swasey among the engineers of this country.

That fine human understanding is not divorced from technical ability is indicated by the following rare tribute which was paid to him by *The Engineer* (London): "To give a list of his works would be merely tiresome, and now, when we are mourning his death we prefer to think of his qualities as a man, his rare and courtly charm, his ability in the selection of the right men for the right positions, the gentle skill with which he trained them, and the encouragement with which he guided them. . . . There are men of firm conviction who gain their way by force of character; there are others, and Aspinall was amongst them, who persuade others to be

of the same mind as themselves. To them is given a greater inheritance in the hearts of their friends."

And there is great need for such executives in all departments of the railways and industries in these days, when employer and employee relationships are of so vital import.

What the Passenger Thinks

The effort which has been exercised in recent years to modernize passenger train equipment; the introduction of high-speed trains, including those of the streamlined type; and the rebuilding of old cars for use on crack trains, has thrown out into strong and positive relief the shortcomings and inadequacy of the older equipment. An article in a recent number of the *Railway Age* by Clarke A. Richards on "See Yourself as Your Passenger Sees You," has started a spirited discussion on the inadequacies of passenger service.

That the railroads are good sports and not averse to constructive criticism is indicated by the fact that they have ordered thousands of reprints of the article for distribution to their employees. Incidentally, many of the so-called "railway fans" have taken issue with some of Mr. Richards' comments, or have come to the support of the railways in an attempt to explain them. Even a railroad enthusiast, however, cannot explain away facts.

While courtesy and service come in for criticism, inadequacies in the equipment and facilities are not overlooked. Antiquated day coaches, poor illumination, filthy toilet facilities, bad ventilation, artistic but insufficient baggage racks, and dirty coaches are matters for which the mechanical department is wholly or partially responsible.

The facts are clear enough; indeed they are admitted on many roads. The problem is what to do about it. The railroads need business. Improvements thus far made, coupled with lower passenger rates and better business conditions, have demonstrated that more up-to-date equipment is appreciated. Living conditions have steadily improved in this country and the dirty, poorly lighted and uncomfortable equipment cheerfully tolerated not so many years ago, will not be put up with or, if it is necessary to use such trains, these conditions will be resented and the patrons will be critical and dissatisfied.

New equipment is being purchased, but it will take

a long time to retire all of the older cars. Wonders can be done, however, at a reasonable and justifiable cost, if there is the will to do it. Much depends on the ingenuity and resourcefulness of the mechanical department in finding ways and means of making the coaches more attractive and comfortable, and in keeping them clean and orderly.

Research Defined

During the depression the railroads were subjected to much criticism for their alleged failure to employ "scientific research" in the improvement of their physical plant. Owing to the dramatization of the more or less spectacular developments which have come from scientific and engineering research laboratories, the impression became strong in the popular mind that the railroads were unprogressive because they had no research laboratory in their front yard. Worse than this, a number of eminent scientists, some pedagogic and some industrial in their affiliations, followed the same uncritical thought process to the same illogical conclusion and, with evangelic zeal, took it upon themselves to convert the railroads to "science." They were dealt with very neatly by Coordinator Eastman.

The two greatest difficulties in the way of a clear understanding of the relationship between research and the railways have been the lack of a suitably qualified and generally accepted definition of the term "research" and the failure to distinguish the fundamental difference in approach to research by the railroads, who are not manufacturers, but purchasers, of their physical facilities, and other industries in which research has been extensively employed in the development of commodities which the industries produce for sale or for their own use. In a paper presented before the February meeting of the New England Railroad Club, L. W. Wallace, Director, Equipment Research Division, Association of American Railroads, has performed a useful service by clearing away both of these difficulties.

Mr. Wallace points out that "the railroad industry is a service industry. It is not a manufacturer. It is not a research agency. It is not a producer of the commodities it uses. Its relation to the commodities it buys and uses is that of a consumer—a purchaser." Continuing, Mr. Wallace says: "The fundamental background or foundation of all the things which the railroad uses is the sum total of the research, development work, engineering ability and experience of all of the producers of the 70,000 commodities which the industry uses, plus its own 100 years of research, development work, engineering and experience."

In defining research as it applies to the development of physical facilities, Mr. Wallace suggests three simple classifications a clear understanding of which should do much to eliminate fruitless discussion and misunder-

standing of the relationship of the railroads to research. He proposes the term "fundamental research" to take in those research activities, the objective of which is to discover the basic principles underlying the universe and the circumstances of life. "Their primary interest is not to increase the financial assets of the world," he says, "but to broaden intellectual horizons." His second category is "creative research," the primary objective of which "is to discover, invent or produce new materials, new processes, new equipment or to find new uses for existing materials and equipment." Creative research, he says, might be called "producers' research," leading to the manufacture and sale of new and improved materials and equipment. Third, he proposes "applied research," the primary object of which is "to determine ways and means of applying to the solution of concrete problems the knowledge, material, equipment and processes made available by fundamental and creative research. It is a process whereby the purchaser or consumer may select intelligently the materials, equipment and processes best suited to his purposes and needs, to the end that increased efficiency, economy and safety may be realized in daily operations."

Further on in his paper Mr. Wallace develops clearly the fact that the railroads, like all consumers, are dependent upon the progress made by those who manufacture and sell the things which the railroads purchase. He also points out that, as the railroads interest themselves in the possibilities for the adaptation of new equipment or materials or functions to the purposes of railway transportation, research and development work are stimulated along many fronts in the industrial world. Thus is clearly suggested the effect of mutual stimulation of the applied research conducted by the railroads and the results of the creative research conducted by the manufacturing industries. Although less publicised than now, this relationship has been a commonplace of the railway industry throughout the century and more of its history. If it were to be written, that history would be a complete record of the advances in applied science and engineering method along America's entire industrial front.

Economy in Freight- and Passenger-Car Design

A study of the age distribution of freight-car inventory in the United States as of January 1, 1936, reveals that there were 763,863 freight cars more than 20 years old; 298,695 cars more than 16 years old; 431,991 cars more than 11 years old; and 279,957 cars more than six years old. The depression necessitated the use of many cars which normally would have been retired, and caused some of the poorest years in the annals of car-building history. With recovery from the depression well under way and, with the possibility that freight and passenger

cars will be built in increasing numbers, the railroads are facing decisions which will determine the extent of the savings to be effected by using materials for car construction which will reduce the tare weight of the cars, increase their capacity and reduce maintenance costs. During depression years, usually conceded as being the time when engineering development reaches its highest levels, low-alloy high-tensile corrosion-resisting steels have been developed which fit the specific need in the transportation field for effecting these savings in car construction. This fact has been appreciated by many railroad mechanical officers.

These high-tensile steels can be used in lighter sections than regular carbon steels for the same service because of the superiority of their physical and corrosion-resisting properties. The stress at the yield point of the high-tensile steels is usually between 50,000 lb. and 60,000 lb. per sq. in., whereas the yield point for low-carbon steels ranges between 25,000 lb. and 35,000 lb. per sq. in. The ultimate stress of between 65,000 lb. and 90,000 lb. per sq. in. for the high-tensile steels compare with ultimate stresses between 48,000 lb. and 65,000 lb. for regular carbon steels. The atmospheric corrosion resistance of the high-tensile steels, which is in some cases four to six times the resistance of plain steel, and its greater yield strength can be utilized for car construction in three ways: (1) In sections equal to regular carbon steel to reduce maintenance costs and lengthen the life of the car structure, with no reduction in weight; (2) in reduced sections to decrease the weight and increase the payload capacity, but with the same strength and same probable length of life as existing equipment, and (3) a compromise between (1) and (2), giving both a substantial increase in service life and a substantial decrease in weight.

In a discussion of savings to be effected by lightweight car construction using high-tensile steels, which followed one of the papers presented at the February 19 meeting of the New York Railroad Club, it was stated that such steels could not be used economically for car construction until the cost was approximately that of regular carbon steels. However, further discussion of the subject revealed that, when the cost of high-tensile corrosion-resistant steel is considered with relation to the strength of such steels, that is, the cost per unit strength, some high-tensile steels on this basis cost less than regular carbon steels. This is now the case because the cost of plain carbon steel has been advanced twice in the past two years while the cost of the high-tensile steels has remained the same, which fact was brought out in the discussion referred to above.

The tare weight of freight and passenger cars which must be moved in order to transport revenue loads is of vital importance to every carrier. Of equal importance is length of the life of the cars and the cost of maintaining them. Improvements in all these factors are being effected by the high-tensile corrosion-resistant steels, and they will undoubtedly have an increasing application in future car construction. This is evidenced

by the fact that over 10,000 cars have already been built utilizing these steels.

NEW BOOKS

STEAM LOCOMOTIVE DESIGN: DATA AND FORMULAE.
By E. A. Phillipson, Assoc. M. Inst. C. E., A. M. I. Mech. E., M. I. Loco. E. Published by the Locomotive Publishing Co., Ltd., 3, Amen Corner, E. C. 4, London, England. 420 pages, 5½ in. by 8½ in., illustrated. Price, \$7.50.

The author has endeavored in this book to include only the essential theory of heat engines and application of mechanics, and to avoid repetition of the most elementary principles and abstruse academic theories which have but limited application to everyday practice. It is written in terms of British practice. Historical details and descriptive paragraphs are avoided, except where they affect present-day considerations of design. While the subject is treated largely from the viewpoint of the locomotive engineer, the book has been written to provide a reference on design for all those concerned with the construction, operation and maintenance of the steam locomotive and to meet the needs of the designer and the more advanced student for a text book covering the subject in the light of recent research and current practice. There are twelve chapters dealing with factors which must be considered before the design of the locomotive is begun; tractive force, power, adhesion and resistance; determination of principal dimensions; boiler design; superheating and feedwater heating; compounding, etc. Numerous drawings of details, etc., are provided, and an Appendix presenting ultimate tensile strength and other particulars of materials for locomotive construction as specified by the British Standards Institution.

DEVELOPMENT OF DRAFT GEARS FOR AMERICAN FREIGHT CARS. *By Wm. E. Gray and C. W. Messersmith. Published by Purdue University, Lafayette, Ind. 150 pages, paper bound.*

This book is a review of the developments leading up to the modern freight service draft gear. It brings into one book comprehensive information regarding practically all early types of draft gears as well as more modern types, this information having been available heretofore only in widely scattered sources. No effort is made to furnish operating characteristics or performance data on the various draft gears described. As stated in the foreword, few devices have been the object of greater inventive effort than the friction draft gear and over 12,000 patents have been issued up to 1927. An effort has been made to exclude draft gears which existed only in patent drawings and to include all draft gears actually constructed, but some have doubtless been omitted in cases where the builder, either through choice or neglect, failed to make a record. A new and hitherto unused system of classifying draft gears on the basis of type of gear action is suggested.

Gleanings from the Editor's Mail

The mails bring many interesting and pertinent comments to the Editor's desk during the course of a month. Here are a few that have strayed in during recent weeks.

Railroad Hobbyists

Many hobbies have sprung up over night, only to die away in a few weeks, and make a goodly number skeptical about model railroading. The patience, skill and investment required in this hobby classes it beyond a "fad". When the newcomer has completed a freight engine, that calls for freight cars and the caboose, then the passenger power and the cars, then the shunting locomotive, more track, switches, signals, still more freight cars. It is easy to see that the model line is infinite.

Make It Fool Proof

I agree with you as to the advantages of air conditioning passenger cars, but in my opinion we still have a long way to go—on some railroads at least. The apparatus must be so improved as to be fully automatic and not require any adjustment or tinkering on the part of the train employees. Something is surely wrong when passengers are made extremely uncomfortable because of too great a spread between the inside and outside temperatures. I don't think much of the judgment of some employees in regulating the temperatures.

Failures of Locomotive Parts

With particular reference to the writings of F. H. Williams, covering failures of locomotive parts, we feel that this is presented in an able manner and shows the extent to which locomotive parts should be designed, machined and later inspected to avoid sharp edged corners and tool marks on finished surfaces, to insure desired service life of manufactured articles. Furthermore, we agree that the chemical and physical laboratory tests are necessary and important in railroad operation, through which medium the cause and reason for failures can be determined, and either improvement of design or better material offered to avoid repeated failure.

Skilled Workers Needed

It seems to me you should put still greater stress in your columns on the vital necessity of recruiting and training young men for the various trades and occupations in the mechanical department. Many of the railroads gave up this effort almost entirely during the depression. The shops were frequently closed for long periods, or ran on short time. Forces were cut down drastically, the older men being favored on a seniority basis. Many of these older men have since retired or have gone into other work. We are hard up against it now for skilled workers and our problem is not made any easier by the fact that the other industries were first to recover and have exhausted the supply of skilled labor. True, many men are still out of work and dependent upon their communities for subsistence. But these are largely unskilled laborers. In this group are too many young men who have never had a chance to learn a trade. Still other young men are coming along who need such training. The railroads must do their part in helping to develop these men for future usefulness, and they will be sorely needed when prosperity gets back into full stride. It is unfortunate that more roads did not follow the example of the Missouri Pacific in maintaining apprentice training throughout the depression; the wisdom of that accomplishment is now becoming evident.

Eyes That Do Not See

Strange, is it not, that we get into such ruts that we fail to see the foolishness or inefficiency in blindly following practices to which we have become accustomed? Possibly they were all right when they were inaugurated, but changing times have made them hopelessly out-of-date. Doubtless this is because our railroad organizations are so large and cover so much territory, although I have noticed the same failing in small industrial organizations, where all the operations were under one roof and where there was keen competition for business. One reason why I cannot get along without the *Railway Mechanical Engineer* is that it is concerned chiefly with informing us about the newest and latest developments and practices. It jolts me out of my self-complacency. And, sometimes, when you do get a good stiff jolt and wake up, the discarded practices look almost ridiculous. What fun a skillful cartoonist could have in showing up our weaknesses. It would be grim humor, but you might even start a column on commonplace practices which are all wrong. A suggestion box on one road has proved helpful in this respect.

Car Failures on Line

The big problem in the car department, and it seems to be getting worse rather than better, is the failure of various car parts in service, no matter how carefully they are inspected before leaving the terminal. These cause bad train delays; they may be classified as follows:

- 1—Car journals run hot.
- 2—Brake beams drop down, usually because of broken brake hangers (a new defect). Also broken brake heads, and broken brake-beam truss rods and fulcrums.
- 3—Trains break in two. This is not always caused by high and low couplers. Sometimes a knuckle may open without any apparent defect; indeed, when recoupled the train may run 150 miles or more to destination without further trouble.
- 4—Brakes stick after brake applications are made while the train is in motion, and sometimes after the so-called running test is made. Train lines also sometimes break.
- 5—Broken couplers and draft gears.
- 6—Broken arch bars and truck side frames.
- 7—Cast-iron wheels, because of shelling, brake burns, worn through chill, slid flat, etc.

Conservation of Man Power

The annual report of the Railroad Y. M. C. A. of Richmond, Va., contains this significant statement: "One of the most serious results of long unemployment is that it unfits men for useful work. Some of the older railroad men, who were laid off during the depression, when called back, found themselves unable to perform the usual duties required of them and were compelled to give up." Your publication called attention to the pre-depression days to the fact that new equipment, changing practices, etc., frequently caused the jobs to outgrow the skill of the workers who were unable to keep up with these changes. Your suggestion then was that the railroads, and industries as well, in order to protect their older employees, should provide special training, so that these workers could adapt themselves to the changing conditions and practices—I think you called it continuation training. Is it not time to put special emphasis on such training, especially with a view to conserving the workers such as are mentioned in the quotation? Do not the railroads, and society in general, owe something to these men? True, they may be to blame because of indifference and lack of initiative but nevertheless, they are with us and must find means of support. Surely their past experience and railroad background will be worth something in conjunction with their new training.

IN THE BACK SHOP AND ENGINEHOUSE

Joliet Locomotive Shop Devices

Several labor-saving devices now in use at the Joliet, Ill., shops of the Elgin, Joliet & Eastern are shown in the illustrations. The first of these, which also incorporates an important safety feature, is the pair of tire clamps used in connection with two short chain lengths and a link for attachment to the traveling crane hook when lifting a locomotive driving-wheel tire to or from the boring-mill table, moving it about in the wheel shop, etc. This type of tire-lifting device, while not an especially new design, is notable because of its simplicity, ease of application and safety, since there is no chance of its being disengaged while there is an upward pull on the lifting chains.

Each clamp is made, as clearly shown in the illustration, of a piece of 2-in. square stock about 11 in. long, bent at one end to fit around the contour of the tire flange and slotted at the other end to receive a $\frac{5}{8}$ -in. by 2-in. by $10\frac{1}{2}$ -in. lever which is pivoted on a $\frac{5}{8}$ -in. bolt and drilled at the upper end for connection to the chain link. An upward pull on the chain holds the hook end of the clamp firmly against the flange and it cannot be disengaged as long as there is tension on the lifting chain.

Horse-Shoe Hub-Plate Jig

In order to avoid the necessity of dropping wheels when taking up trailer and driving-wheel lateral play, many E. J. & E. locomotives are equipped with removable brass hub plates which are attached to the trailer or driving boxes by special flat-head bolts through four projecting ears cast integral on the hub plates, these bolts extending through into the boxes so as to position the hub plates properly and being removable through holes between the wheel spokes. This allows a worn hub plate to be removed and replaced by a thicker one without dropping the wheels.

The hub plate is made somewhat in the form of a horse-shoe, being open at the bottom to accommodate the grease cellar. The hub plate is machined in a special

cast-iron jig $20\frac{5}{8}$ in. in outside diameter by $4\frac{1}{8}$ in. high, being centered on the boring mill table and held down to the table, as well as held against turning, by means of four finger clamps, only one of which is illus-



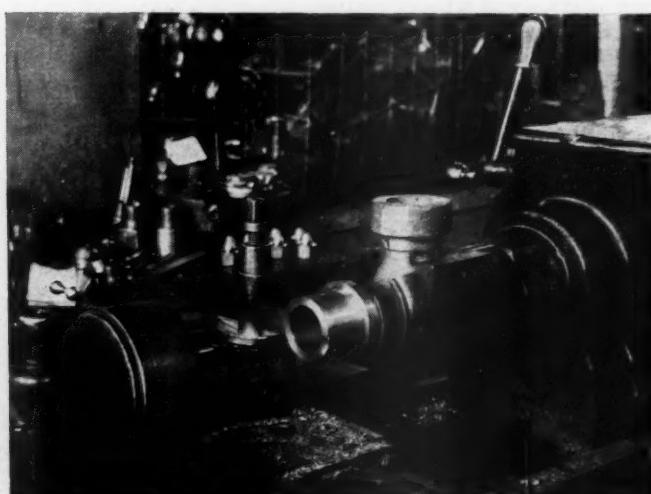
Machining a removable horse-shoe hub plate in a special boring-mill jig at the Joliet shops

trated. The horse-shoe hub plate, as received in the rough casting, fits into a recess $19\frac{3}{8}$ in. in diameter by $\frac{3}{8}$ in. deep in the top of the jig, the four ears projecting out through suitable openings. The hub plate is held against turning in the jig by means of these ears and is held against lifting out by means of seven $\frac{3}{8}$ -in. set screws arranged around the periphery of the jig. In order to prevent the hub plate from springing in under clamping pressure, two stops are cast on the jig which just fill the grease-cellars opening in the hub plate and thus add to the rigidity of the clamping arrangement.

This cast-iron jig is cored on the inside to reduce weight. It is centered by means of a projecting center



Hand-operated wash-out-plug chaser used in an enginehouse



Jig for machining a boiler-check goose neck

piece 6 in. in diameter by $\frac{3}{8}$ in. deep, which fits into a center hole in the boring-machine table. The jig is driven by four finger clamps, as mentioned. A rough and a finish cut are taken on one side of the hub plate which is then turned over and machined to the required thickness.

Goose-Neck Machining Jig

A special jig for machining boiler check goose necks is shown in the illustration. This consists of a recessed steel block $4\frac{1}{2}$ in. square by $4\frac{3}{4}$ in. long, threaded on one end to fit the brass lathe spindle and threaded on the other end $4\frac{5}{8}$ in. in diameter by $1\frac{1}{8}$ in. long to receive a brass collar (shown on the lathe dead center) which serves to bring the goose neck squarely up against a spacing collar on the jig and centers it with respect to the lathe spindle and dead center. This permits turn-



Tire-lifting clamps which combine simplicity, ease of application and safety

ing, facing, boring and threading the ends of the goose neck with a minimum of set-up time and the assurance that the goose neck will not be ripped out of some insecure clamping arrangement on a face plate or chuck. Extra brass clamp adapters are available for different sizes of goose necks.

Wash-Out Plug Chaser

A simple little device which proves a great convenience in enginehouse work is the wash-out-plug chaser, shown in the illustration. The threads of brass wash-out plugs, even when removed every 30 days, frequently become pretty well filled with lime, carbonized oil and other foreign material which is difficult to remove by ordinary hand methods, especially without some damage to the threads.

The device shown in the illustration consists simply of a hand wheel and chuck arrangement for turning the wash-out plug while a hand thread chaser is used to run up the thread and clean out all foreign material without removing any metal. The entire jig is mounted on a U-bracket made of 2-in. by $1\frac{1}{4}$ -in. stock measuring 8 in. between the vertical sides and 6 in. high. This bracket is bolted to a supporting plate on a tool box and equipped with a 12-in. hand wheel, friction bearing and driving jaw on one side and a tail stock with a 4-in. hand wheel and $\frac{3}{4}$ -in. screw on the other side to hold the wash-out plug in the driving jaw and also center it. The driving jaw also is equipped with a center so that the wash-out plug will run true. A tool rest is provided parallel to the center line of the device and on the side next to the workman. This serves as a guide and sup-

port for the hand-operated thread chaser tool as it is moved parallel to the axis of the wash-out plug and cleans out the threads.

Locating Dead Centers on Gas and Diesel Engines

The matter of accurately determining the exact dead center of some internal-combustion engines, due to their construction, is often an awkward procedure. The location and size of the spark-plug or injection-nozzle openings discourage the usual practice of feeling for the piston through these holes. In such cases, the crank case must be opened and the crank cheeks plumbed by the means of a bevel protractor.

Due to the inaccessibility of a machined surface known to be at the correct angle from the cylinder center lines, the protractor cannot be checked properly to determine whether the engine is level—a fact which depends en-

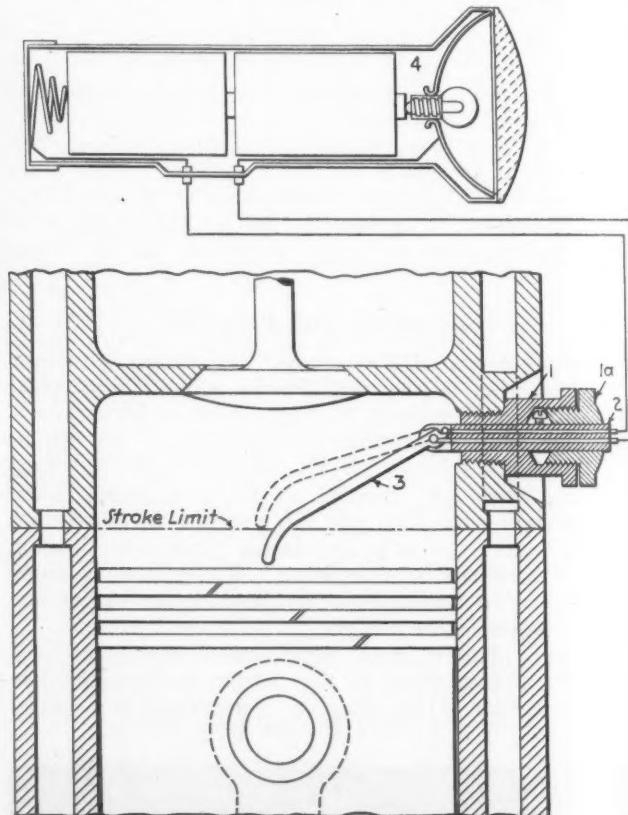


Fig. 1—Device for locating dead centers and timing ignition of internal-combustion engines

tirely on track conditions and the poise of the car or locomotive in which the engine is mounted.

A device that can be used to locate these dead centers easily and accurately is shown in Fig. 1. The material required for making the device is a spark plug, a flashlight, a short piece of round fiber rod, some pieces of $\frac{1}{8}$ -in. and $\frac{3}{16}$ -in. Tobin bronze welding rod and some short lengths of insulated wire. This device will not only give the piston position accurately but also lets the operator know when the piston is on the compression stroke without dismantling the cylinder-head covers or valve panels to expose the action of the intake valve. Fig. 1 shows the design and application of the device to a vertical, valve-in-head motor of conventional design. Fig. 2 illustrates its use in dead-centering and timing the

ignition of a 12-cylinder, four-cycle, valve-in-head motor. To make the device, a spark plug is first procured, the porcelain insulator is then removed, and the holes in both members of the spark plug are reamed to accommodate a straight cylindrical insulator made of fiber. This insulator 2 is shown in Fig. 3. The assembly of this insulator and the reamed spark plug is shown in Fig. 4. One end of the insulator is slotted to provide jaws for the hinging of the feeling lever 3. The insulator 2 is drilled longitudinally to receive the hinge electrode 2a

point near its upper stroke limit ($\frac{1}{4}$ in. is sufficient). It is obvious that as the piston approaches the upper limit of its stroke and encounters the feeling lever 3, the flashlight circuit is broken and the light goes out. Now, if crankshaft be turned further in the same direction, the piston will reach its stroke limit, after which it descends. When it reaches the exact spot at which it contacted lever 3 on the up stroke, it will again release lever 3; this closes the flashlight circuit causing it to light until the next interference by the piston on its next

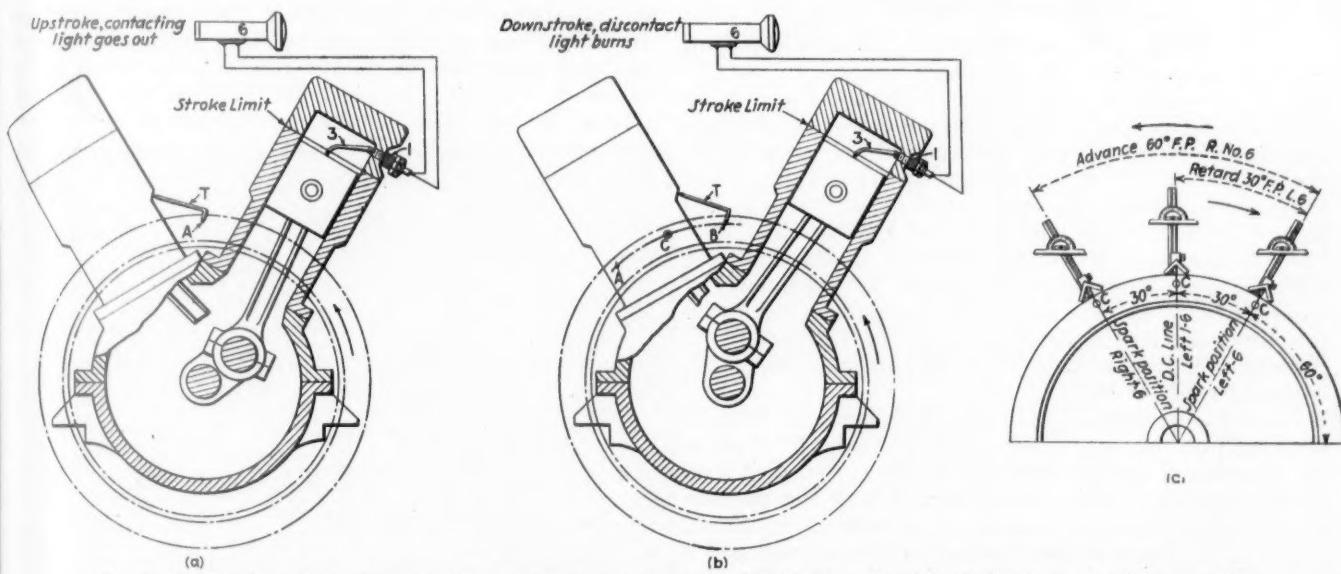


Fig. 2—Application of the device for locating dead centers and timing ignition of a 12-cylinder four-cycle V-type engine

and contact electrode 2b, which are secured in a functional position by the set screws 2c. A small vent groove 2d is cut along one side of insulator 2 as shown in Fig. 3. This vent provides a means of compression escape and serves also as a warning port when determining the compression stroke of the cylinder. Both electrodes 2a and 2b have one end bent at right angles to form an L shape. These L ends are sawed short enough to bridge the space between the jaws of the insulator 2. The L section of the lower electrode 2a acts as a fulcrum for feeling lever 3. Lever 3 is provided with a limit lug 3a as shown in Fig. 3, which limits the downward swing of lever 3 to a fixed angle by its contact with upper contact electrode

stroke. Since air will be expelled through a spark-plug or fuel-nozzle hole only on the compression stroke of a four-cycle engine, when turned in its intended direction of rotation, the vent 2d shown in Fig. 3 serves to warn the mechanic that the piston is approaching the position desired for locating the first dead center.

A tram should be used with this device to locate dead centers. This tram should be fulcrumed from some fixed object or part of the engine and scribing should be done either on the face or rim of the flywheel. To avoid confusion in taking protractor readings, the tram should be of a length that will fix a point on a vertical line with the crankshaft. However, this is not imperative. After the tram is procured and the device is in position in the cylinder with the proper connections made to the flashlight, the flywheel is turned in the direction of rotation until air is expelled from vent port 2d. Continue to turn carefully in the same direction until the first flicker of the flashlight, then stop. Scribe a short line across the face of the flywheel with the tram,

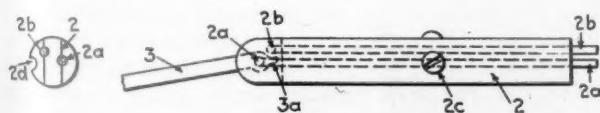


Fig. 3—Fiber insulator for the spark-plug assembly

2b. Since electrodes 2a and 2b are conductors of electricity and are completely insulated from each other by the fiber body 2, it is obvious that lever 3 through its limit lug 3a provides a means of making and breaking an electrical circuit. Hence, the assembly forms an effective and sensitive switch for the flashlight 4 shown in Fig. 1, from which the regular switch has been removed. The terminal of the flashlight 4 are wired directly to the locator as shown in Fig. 1. By using No. 6 machine screws for set screws 2c, and so locating them that their heads occupy the recess formerly occupied by the flange of the porcelain, a means is provided for securing the insulator 2 in position within the outer shell 1 and 1a. The shape of feeling lever 3 is such that when the device is screwed in the regular spark-plug hole, its feeling end will contact the piston when the latter has reached a

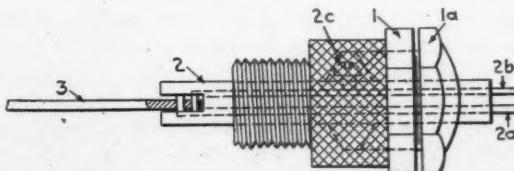


Fig. 4—Spark plug with insulator assembled

as shown in Fig. 2a at A. Now again turn the flywheel carefully in the same direction. The flashlight will now be observed to be not burning. Continue the turning until the next flicker of the flashlight, indicating the point of re-contact, and stop. Now with the tram make another mark B on the flywheel, as shown in Fig. 2b.

Next with a pair of hermaphrodite calipers, scribe an

arc parallel with the perimeter of the flywheel, bisecting marks *A* and *B*, shown in Fig. 2*b*. With a pair of dividers, locate a center mark *C* equidistant between marks *A* and *B*. Turn the flywheel back until the tram registers with the center mark *C*. This places the piston of the cylinder to which the device was placed on its exact dead center, regardless of the angularity of the cylinder center line of the motor.

Timing the Camshaft of a 12-Cylinder four-cycle Engine

When timing the camshaft of a 12-cylinder, four-cycle gasoline engine, the intake of which is to start 10 deg. in retard, the left No. 6 piston is the most convenient to dead center. As cylinders No. 1 and 6 are running mates, that is, their crank pins are at the same angle, the No. 1 and No. 6 pistons are on dead center at the same time. Hence, the dead-center mark that was just located for left No. 6 will serve for left No. 1 as well. Now with a bevel protractor, with its blade registering with the dead-center mark *C*, adjust the spirit level of the protractor so that its bubble neutralizes. Note at this time, the reading in degrees of the protractor. If the engine is level and the tram was made as suggested, it should read 90 deg.

Next set the protractor to read 100 deg., and with its blade still on the dead-center mark, turn the flywheel in the direction of rotation until the bubble of the spirit level of the protractor again neutralizes. Check the position of the intake valve of left No. 1 cylinder. It should just start to open with the flywheel in this position and if the tappet clearance is properly adjusted. If it does not start to open, the timing gears or chain should be unmeshed, and the camshaft should be turned until the left No. 1 intake valve just begins to open. The gears or chain should then be remeshed. To time the camshaft of the right-hand section of the motor, set the protractor to read 160 deg., turn the flywheel further in the direction of rotation until the spirit level neutralizes, and then check and correct the right camshaft the same as was done with the left.

Timing the Ignition of a 12-Cylinder four-cycle Engine

Left Side—When timing the ignition on the left side of a 12-cylinder, four-cycle gasoline engine, the ignition of which takes place 30 deg. in advance, set the protractor at 60 deg., turn the flywheel against rotation until the spirit level neutralizes when the blade is registering with the dead-center mark *C* shown in Fig. 2*b*. With the flywheel in this position, the left distributor should be so set that its breakers are just separating when the high-tension rotor is in communication with the left No. 6 terminal. The same applies if magnetos are used. If correction is required, the distributor or magneto shaft gears should be disengaged, and the distributor or magneto shaft should be turned in its direction of rotation until the breakers just begin to separate. Where dual ignition is used, care must be taken to avoid confusion in setting distributors and magnetos, since one of these operates in a clockwise direction while its mate operates in a counter-clockwise direction.

Right Side—When timing the right-hand side of the engine, set the protractor at 120 deg. and turn the flywheel in the direction of rotation until the spirit level of the protractor neutralizes with the blade registering on the dead-center mark *C* shown in Fig. 2*b*. Recheck or correct the right distributors the same as was done

with the left. Fig. 2*c* illustrates the setting of ignition for a 12-cylinder, four-cycle engine as herein described. Since the connecting rods on the right side of a 12-cylinder engine connect to the same crank pins as do the connecting rods on the left side, and since the cylinder center lines are at an angle of 60 deg. from each other, it is obvious that one dead-center mark will serve both sections of the engine by protracting the intake and ignition events of the right section exactly 60 deg. in retard of the same marks of those of the left side.

It is good practice to stencil the flywheel at the time each event position is protracted. With the flywheel set in the position of each event as ruled by the protractor, strike a mark on the flywheel and permanently prick punch or birdseye punch that mark on the flywheel. These may be identified by appropriate abbreviations; for example, "F.P.L.6" could be used to designate

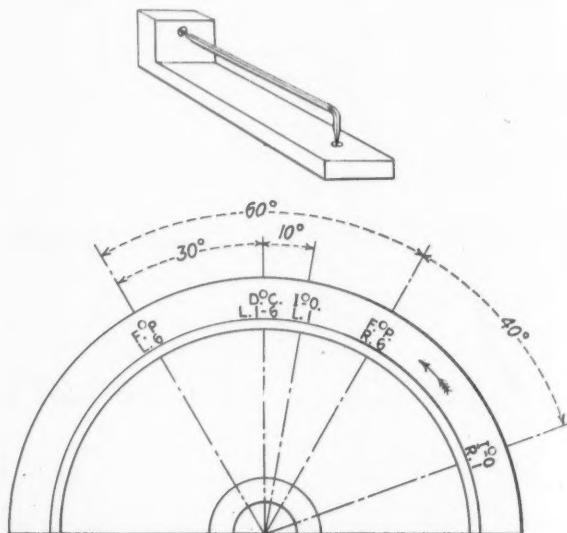


Fig. 5—Master gage for tram and flywheel layout with permanent timing and dead-center marks

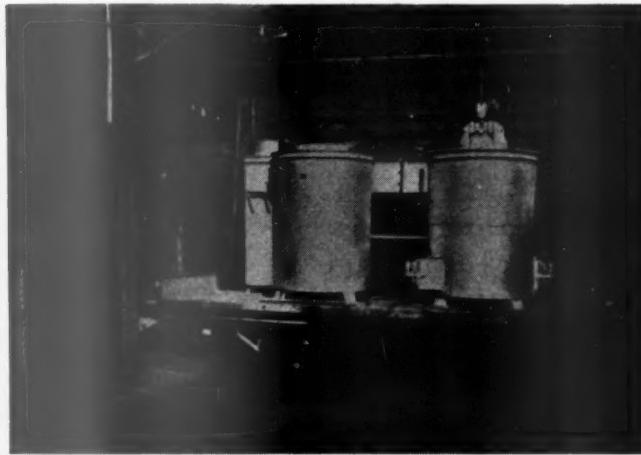
"firing point Left No. 6." Then in the event of future time checkings or dead centerings, it would only be necessary to use the tram and turn the flywheel directly to the mark sought for rechecking, thus eliminating the use of the locator and bevel-protractor that are only required for the initial layout of the flywheel. Much time can be saved by this practice. The tram should be carefully preserved by the mechanic responsible for the maintenance of the motor. A simple master gage made of bar stock should be kept with the tram, to check it for correct length from time to time. Such a tram and master gage, and also the flywheel layout, are shown in Fig. 5. The layout marks shown in Fig. 5 have the following meanings: "F.P.L.6" locates the firing point of the left No. 6 cylinder; "D.C.L. 1-6" locates the dead-center position of left No. 1 and left No. 6 pistons; "I.O.L. 1" locates the point where the intake valve of left No. 1 cylinder is just beginning to open; "F.P.R. 6" locates the firing point of the right No. 6 cylinder; and "I.O.R. 1" locates the point where the intake valve of the right No. 1 cylinder is just beginning to open.

This device may be used in locating dead centers of Diesel engines in timing their admission and fuel-injection periods. The outer shell of the locating device, however, would have to be made to fit the glow-plug holes or injection-nozzle holes, whichever is the most convenient. A flashlight is recommended for use as a signal for this device for the reason that a light of higher voltage would arc at the electrode contacts when the piston makes its up-stroke contact.

Hardening Crosshead Guides In Salt-Bath Furnaces

The case-hardening of crosshead guides has presented an expensive problem for the German State Railways for many years. When repairs are judged necessary, the practice is first to test the guides for hardness, and if a figure of less than 60 Shore is obtained the guides are carburized. In order to obtain the most economical results, guides are sent to a central shop for hardening so that the furnace plant can be operated continuously throughout a 24-hr. day.

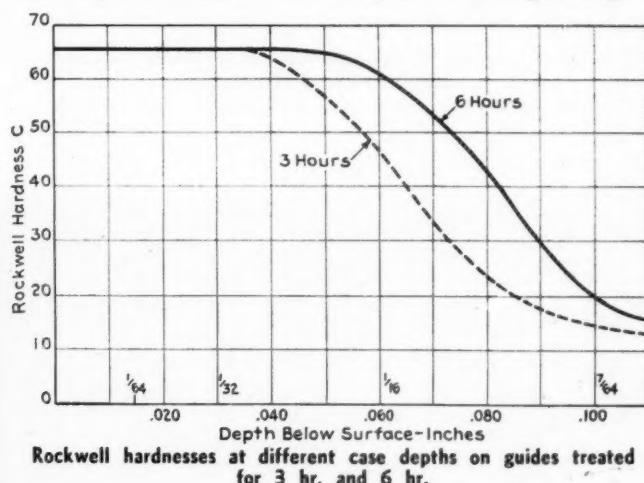
One such central shop is located near Bremen where it was ultimately found necessary to take care of from



Salt-bath furnace at Bremen, Germany, for case-hardening crosshead guides

100 to 150 guides per month. Since the pack-hardening type of furnace which was installed at this plant had a maximum output of only 120 guides per month, it was decided to investigate the possibilities of salt-bath furnaces for this work. Molten-sodium-cyanide furnaces have long been used for case-hardening small steel parts which require a maximum penetration depth of only 1/32 in. However, the possibilities of the process have recently been extended by the development of deep-

cementation compounds of a type which, in Europe, are marketed under the name of "Durferrit C 5." Briefly, the main advantage of such compounds is that they enable a case of 0.045 in. to be obtained in 3 hr., and a case of 0.075 in. in 6 hr. Furthermore, the eutectoid zone obtained with this latter process is from one half to five-eighths of the total depth of the case, which permits the removal of considerable stock by grinding, without exposing the soft core of the guide. This grinding is



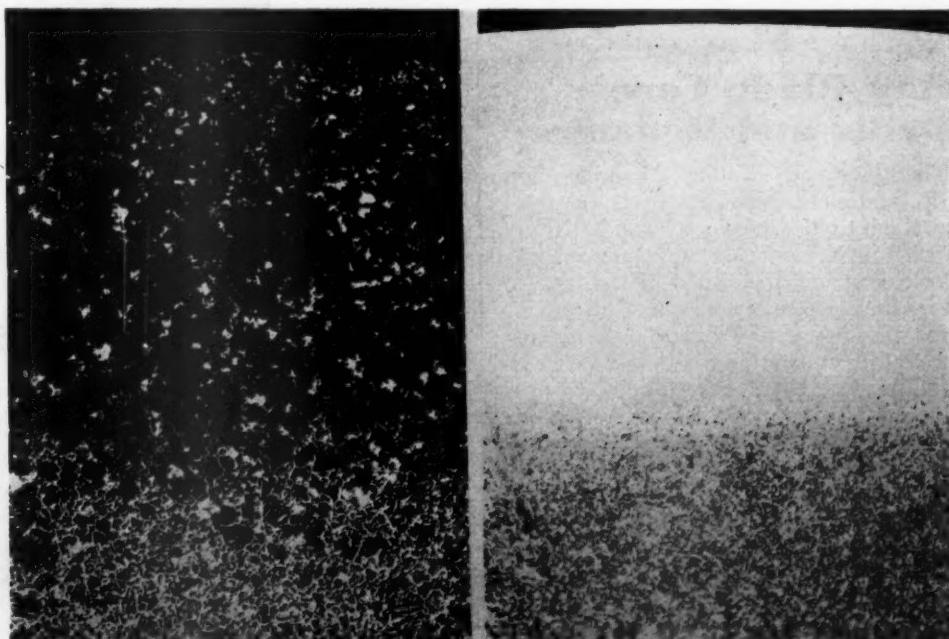
Rockwell hardnesses at different case depths on guides treated for 3 hr. and 6 hr.

necessary in order to correct any distortion which may have occurred in the furnace.

Largely as a result of the increased speed of working rendered possible by the process, it was decided to install a salt-bath furnace for the purpose of taking care of the increased output of 150 guides per month. The furnace that was installed has a pot diameter of 14 in. and a depth of 78 in. and, like the pack-hardening furnace which it replaced, it is oil fired. The guides to be hardened are suspended vertically in the molten bath. Waste heat is passed through a preheater where it serves to preheat the next component to be treated. The oil burners, of which there are two, operate under an air pressure of 16 in. of water, and consumes 1½ gal. of oil per hr. Combustion requirements demand 425 cu. ft. of air per min. Under these conditions the average life of the bath is between 700 and 800 working hours.

A certain amount of distortion is inevitable in any

Microstructure of case-hardened guide at different magnifications



case-hardening operation, but it has been definitely ascertained that the amount of distortion is less in the salt-bath process than when the pack-hardening method is used. In addition, a comparison of the old and the new methods shows an interesting economy in fuel resulting from the change-over; the essential cost data for the two methods are shown in the table. The graph shows the Rockwell C hardnesses obtained on work which has been carburized in the salt-bath furnace for

Cost of Hardening Crosshead Guides by Pack-Hardening and Salt-Bath Methods

	Pack-hardening method *	Salt-bath method
No. of guides per heat	4	1
Carburising time, hrs.	12	3
Total time for four guides, hrs.	12	12
Weight of hardening compound, lb.	106	...
Weight of salts, lb. ....	...	9
Oil consumption in 12 hr., gal.	79.5	18.5
Cost of oil used in 12 hrs.	\$8.66	\$2.02
Cost of hardening compound	\$2.06	
Cost of salts ....	...	\$2.16
Incidental costs per 12 hrs.	\$2.40†	\$1.92‡
Cost of insulating ends of guides with asbestos and clay per 12 hrs.	\$0.24	...
Cleaning guide before carburising, and reheating ends subsequently per 12 hrs.		\$0.96
Wages for 12 hrs.	\$3.08	\$3.08
Total cost per 12 hrs.	\$16.44	\$10.14
Cost per guide	\$4.11	\$2.53

* Two furnaces.

† Wear and tear on boxes.

‡ Wear and tear on crucible and pyrometer thermocouple.

3 hr. and 6 hr., respectively, at a temperature of 1,760 deg. F. It will be noticed that the depth of case obtained by the process is 0.045 deg. in 3 hr. and 0.075 deg. in 6 hr. and of these cases 0.025 in. and 0.040 in., respectively, are "glass hard." The structure of the case obtained is shown in the microphotographs, which indicate that no free cementite is present, and that more than half the case is completely saturated with carbon.

In summarizing the advantages of hardening guides in salt-bath furnaces, it is seen that the cost per guide is \$2.53 as against \$4.11 with the pack-hardening method; that less time is required for carburizing; and that although the depth of the case is practically the same for both methods, the distortion is less with the salt-bath furnace.

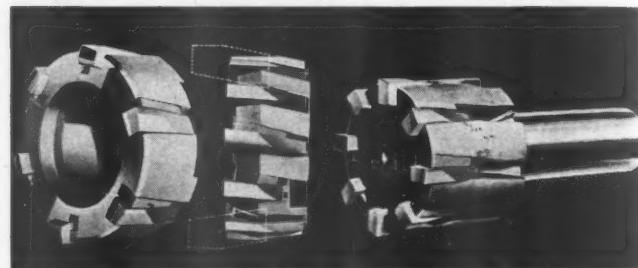
Ray Blade Core Drills and Reamers

The Ingorsoll Milling Machine Company, Rockford, Ill., announces that the Ingorsoll ray blade can now be applied to the heads of solid-shank or shell-type core drills or reamers. The double-tapered ray blades are locked against the thrust of the boring cut. When worn they are reset any amount by moving them outward for resizing and forward to compensate for the major wear of end cutting.

The ray blade is a double-tapered blade positively locked in the cutter housing with a compensating serrated wedge. The cutter blade is tapered along its length so that it will not push down or back from the thrust of the cut. It is further dovetail tapered across its width to prevent it from pulling out of its locating slot. The blade is retained in position by a double-tapered serrated wedge. As the cutter blade is moved outward for regrinding for wear, the clever shape of the wedge permits its movement, either further along

or down its serrated slot. The wedge thus compensates for the thinning movement of the ray blade.

Ingorsoll ray-blade boring heads are furnished with

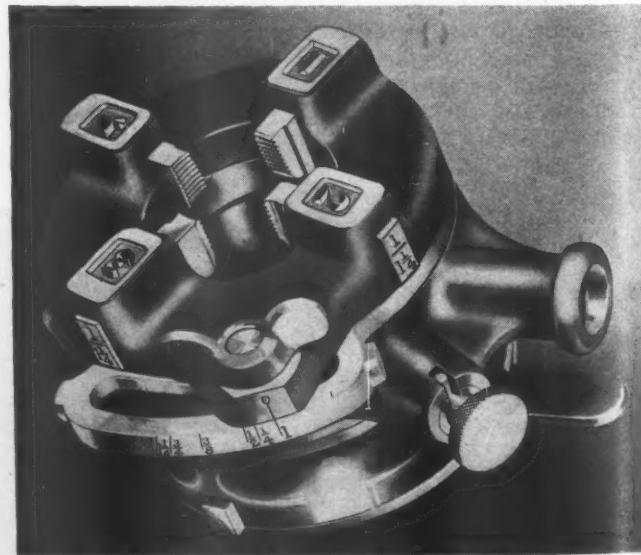


Shell-type and solid-shank boring heads for core drills or reamers with Ingersoll Ray blades

blades of high-speed steel, super-high-speed steel, Stellite, or tipped with cemented carbide fitted into housings of forged and heat-treated alloy steel. The shape of the blade makes it particularly economical for cutters with Stellite blades.

Wide-Range Ratchet Die

The illustration shows a ratchet die for threading pipe ranging in diameter from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. Three sets of dies, each for threading two sizes, can be changed quickly and are fully adjustable for cutting standard, oversize and undersize threads. The first set of dies cuts threads from $\frac{1}{4}$ to $\frac{3}{8}$ in., the second set cuts threads from $\frac{1}{2}$ to $\frac{3}{4}$ in., and the third set cuts threads from 1 to $\frac{1}{4}$ in. A three-jaw self-centering chuck centers the pipe in the ratchet



The Beaver ratchet die for threading pipe which has a range from $\frac{1}{4}$ in. to $\frac{1}{2}$ in.

without the aid of bushings or grip screws. The threading dies are above the face of the stock so that the chips fall away from the thread as they are being cut. The ratchet and ratchet pawl are of extra-heavy air-furnace malleable iron and have a rust-proof finish. The die, designated as the No. 60-R ratchet, is manufactured by the Beaver Pipe Tools, Inc., Warren, Ohio.

With the Car Foremen and Inspectors

Box Car Rebuilding on the E. J. & E.

The Elgin, Joliet & Eastern is now rebuilding a series of 450 forty-ton U. S. R. A. box cars into a modern design with Pullman Standard Cor-Ten steel sides, Murphy rigid steel roofs with depressed running boards, Creco side doors, Miner and Peerless draft gears, Type-E couplers with bottom-operated lifting lever, Cardwell-Westinghouse snubbers, Type AB air brakes, Miner power hand brakes and Apex defect card holders. The original cast-steel trucks of the Andrews type are retained and equipped with one-wear rolled steel wheels.

By the use of the pre-fabricated thin steel car sides, the inside car width is increased from 8 ft. 6 in. to 8 ft. 9 $\frac{1}{2}$ in. and the elimination of carlines by the use of the new rigid steel roof provides a slight increase of inside height from 9 ft. to 9 ft. 2 in. The new car is 40 ft. 6 in. long inside and weighs 44,600 lb., as compared with 45,400 lb. for the old car.

Among the important changes in the detail design and construction of the rebuilt cars, as compared to their predecessors, is the use of a floor reinforcing angle applied longitudinally between the center sill and each side sill to give additional strength for heavy trucking operations on the floor. Modern lightweight alloy steel sides replace the former wooden sides, the original Murphy steel ends being retained. A Murphy rigid steel roof replaces the flexible steel roof formerly installed.

A small but rather important detail in connection with the floor design is the application of post fillers, as shown in one of the illustrations, longitudinally over the side sill and extending the width of the post. This eliminates fitting the decking around the side posts and supplies a firm support for the bottom lining boards, which protects them against displacement through load shifting or trucking movements. Another feature is a shield made of $\frac{1}{4}$ -in. by 15-in. by 30-in. steel plate riveted to the bottom of the side sill and suitably braced, as shown

in another illustration, this shield serving to protect the service and emergency portion of the AB brake valve which, when left exposed, is frequently damaged by trucks when backing up to the car door.

To facilitate repairs, the side ladders are attached at the top to the W-section and at the bottom to the side sill in such a way that it is not necessary to go into the car



Steel plate applied as a protection in front of the Type AB brake valve

and tear out the lining to renew or replace ladder bolts. End-sill grab irons also are applied to brackets below the bottom line of the end sill for the same purpose. Metal brake steps are applied. No effort is spared to make the car watertight, especial attention being given to the corner caps which are carefully welded at all joints.

An interesting feature of the inside finish of the car is the use of a door-post filler made in two pieces, one of



Rebuilt box cars being stenciled outside at Joliet shops



Car frames stripped ready for rebuilding—New Cor-Ten steel sides (loaded on gondola in background) as received from Pullman-Standard ready for application

which is a $1\frac{1}{2}$ -in. by $2\frac{1}{4}$ -in. section set in the corner and used as a nailing strip for grain doors. This inserted strip can be readily renewed when necessary without removing and replacing the entire door-post filler piece. The end lining is made of the same material as the floor, being $1\frac{1}{2}$ -in. yellow pine. A feature of this construction is the use of a strap, made of $\frac{1}{4}$ -in. by $1\frac{1}{2}$ -in. steel, set in horizontally at a level of about 48 in. above the floor and bolted through the end lining into the steel end. This steel strap has been found an important aid in keeping the lining in place under impact shocks when the car is in service.

Description of the Rebuilding Operations

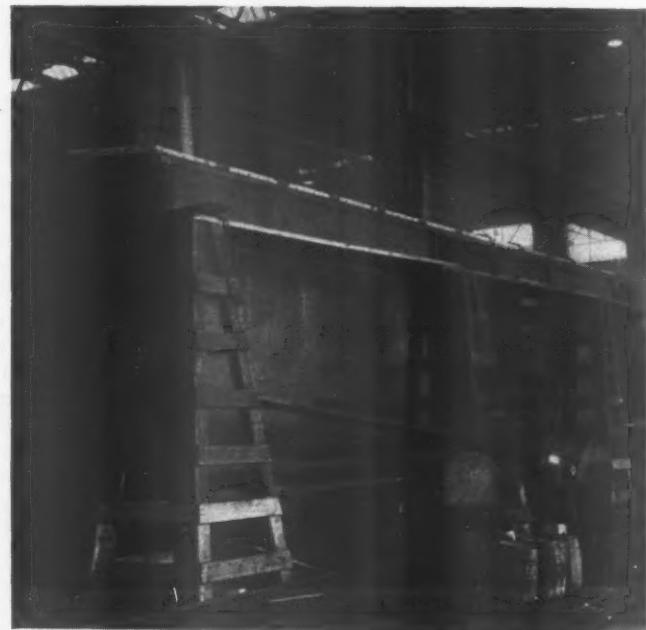
The cars are stripped of all wooden parts down to the underframe on a stripping track outside of the main shop, the ends being the only part of the superstructure retained. The cars are moved to another station outside of the shop where the ends are removed and sent to the hydraulic press for straightening. Underframe repairs are made at this station, also truck repairs, and AB brakes applied with extra-heavy piping.

The cars then move into the shop to a station where the sides and ends are applied, the latter having been drilled with any necessary holes for new applications, such as end ladders, power hand brake, etc. The sides, shipped from the manufacturers compactly loaded in low-side gondolas, are applied with the shop crane inside the shop, using an equalizer bar with special clamps attached to the W-section. This arrangement avoids any tendency of the light side panels to buckle.

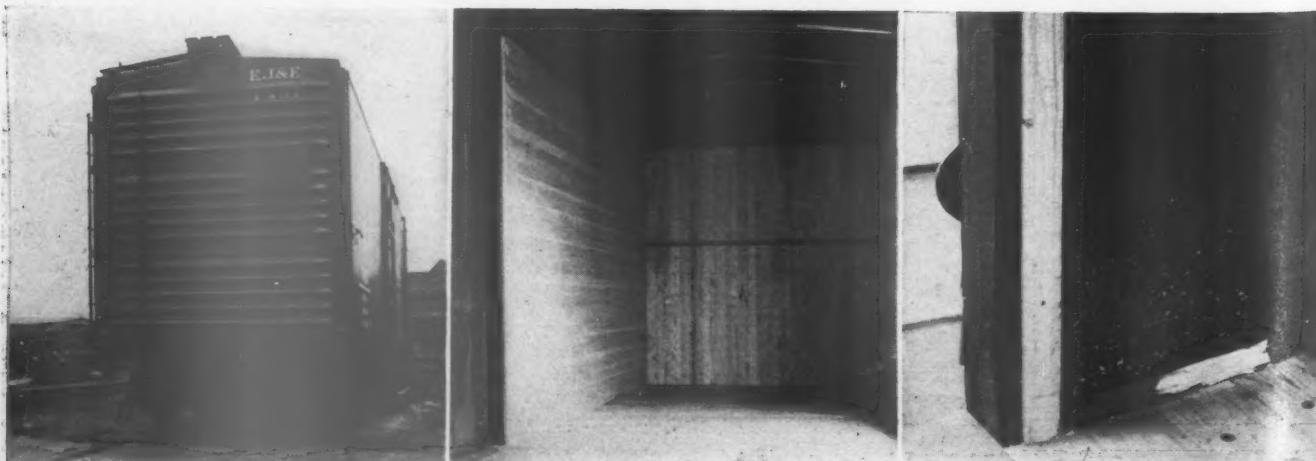
At the next station, all holes in the sides and ends are reamed, and rivets, later to be blanked, are driven at this time. The roof, assembled and driven on a jig on

the ground, using special pneumatic riveting tools, is applied, an equalizer lifting bar being used in this instance also to avoid buckling of the light roof structure. Next, the doors are applied, also the corner caps; inside corner bands and caps are applied and riveted.

Side ladders are applied and roof rivet holes reamed. Four hammer operators are used in riveting the roof,



The station where car sides and ends are riveted



End of rebuilt car (left)—Interior lining, floor and roof (center)—Detail of door post and side-post filler (right)

each driving one-half of a side and one-half of an end. The hammer man works on the inside where a scaffold is provided. A two-tier scaffold on the outside provides convenient footing for the rivet buckers. At the corners, rivets are driven from the top down to where they can be reached by the ground man.

The car moves to the next position where one man at each corner drives the remaining rivets. The flush running boards are applied with the bolts having slotted heads tightened with an electric screw driver.

The steel work is completed and the car moved with a tractor outside of the shop to a position where creosoted wood side nailing posts and the end nailing fillers, also side post fillers, are applied. The entire inside of the car is given one coat of mineral paint (the priming coat having been previously applied). Floors are applied, consisting of $2\frac{1}{2}$ -in. yellow pine, bolted with water-proof bolts. The side lining consists of $3\frac{1}{4}$ -in. wide vertical grain fir applied the full length from door posts to ends. The end lining is applied as described.

Cars are spray painted and stenciled in accordance with the usual practice. An output of five cars a day is secured with a total force of about 270 car men.

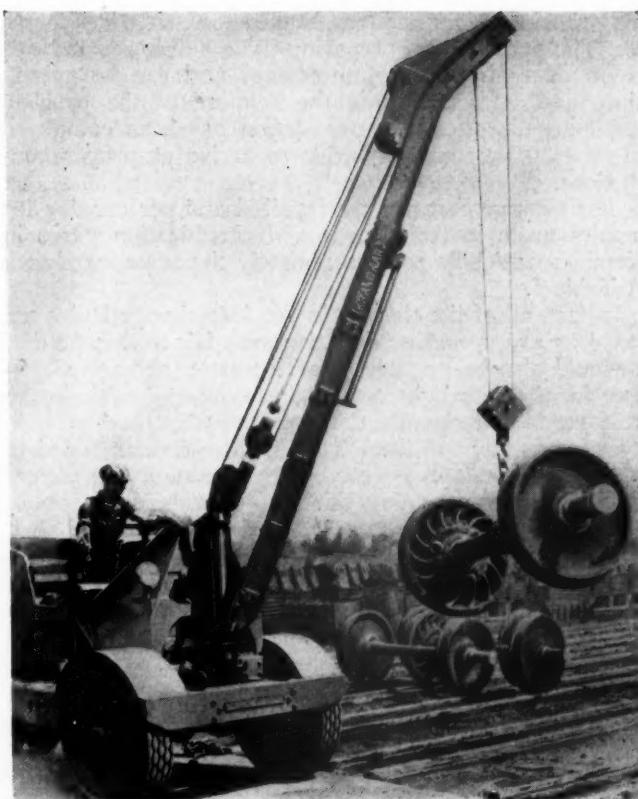
Diesel-Powered Industrial Crane

The industrial crane shown in the illustration is one of two standard self-propelled live-boom units manufactured by the Silent Hoist Winch & Crane Company, Brooklyn, N. Y. Each of these standard cranes, which have capacities of 5,000 lb. and 10,000 lb. respectively, are called "Krane Kars," and are powered with a Buda "Hivelo" four-cylinder engine capable of developing 55 hp. at 2,700 r.p.m. and 26 hp. at 1,000 r.p.m. The chassis of both cranes are of welded-steel construction with 36-in. diameter by 10-in. wide rubber-tired tractor wheels in front at the base of the boom, and 24-in. diameter by 5-in. wide rubber-tired steering wheels at the rear. They are furnished complete with power-swinging power-topping booms, electric lighting and starting equipment, air cleaner, oil filter, front bumper, a two-man seat, four lashing hooks, and a tool box as standard equipment.

The load hoists and boom-topping hoists of these cranes are operated by enclosed self-contained reversing mechanisms with $\frac{1}{2}$ -in. cables of 5,000-lb. single-line capacity winding on 7-in. drums. The boom-topping hoist operates entirely independently of the load hoist. The boom swing is controlled by a self-locking worm and sector and is automatically held in any position of swing. Automatic positive limit stops are provided to control the swing and topping motions of the boom.

The 5,000-lb. capacity crane can manipulate a 5,000-lb. load at a 5-ft. radius; this gives a clearance of $3\frac{1}{2}$ ft. at the front of the crane. In a diagonal position the capacity is 7,000 lb., while at 10-ft. radius the capacity is 2,500 lb. The standard boom is 11 ft. long but 14-ft. and 17-ft. telescopic booms are also available. The overall width is 5 ft. 6 in., the overall height is 7 ft., and the overall length is 10 ft. 7 in., exclusive of the boom. This model has four traveling speeds up to 15 m.p.h. as well as one reversing speed. The hoisting speed, with power take-off in high gear, is 50 to 80 ft. per min. Boom-topping from horizontal to vertical requires 8 sec. The boom can be swung through 180 deg. in 15 sec. The 5,000-lb. capacity crane weighs 14,500 lb., exerts 4,500 lb. tractive force and has a turning radius of 12 ft.

The 10,000-lb. capacity crane can manipulate 10,000



A 5,000-lb. capacity Krane Kar in service on the Missouri Pacific

lb. at a 5-ft. radius which leaves a clearance of $3\frac{1}{2}$ ft. in front of the bumper. The capacity at a 10-ft. radius is 5,000 lb. The standard boom is 12 ft. long but 14-ft. and 16-ft. telescopic booms are also available. The crane has four forward speeds up to 12 m.p.h. and one reversing speed. Load hoisting is accomplished on a three-part line at speeds of 35 to 55 ft. per min. with power take-off in high gear. The topping-boom can be raised from a horizontal to a vertical position in 10 sec. The boom can be swung through 180 deg. in 19 sec. The overall width of this model is 6 ft. 2 in. The overall height is 7 ft. 7 in., and the overall length is 11 ft. 1 in., exclusive of the boom. It weighs 21,000 lb., can exert a tractive force of 6,500 lb. and has a turning radius of 6 ft. 6 in.

Discussion of A. A. R. Interchange Rules*

By J. C. Hayes†

We should all benefit by discussion of Interchange Rules and thereby obtain a clearer understanding of just what they contemplate. This paper consists of six subjects for consideration and discussion.

Should the Preparation of Billing Repair Cards in Train Yards and Classification Yards Be Discontinued?

We all know that billing repair cards prepared in train yards and in classification yards cover light run-

* Abstract of a paper presented at a meeting of the Eastern Car Foremen's Association of New York, held in New York City, January 8, 1937.

† Supervisor, A.A.R. Clearing House, New York Central System, Buffalo, N. Y.

ning repairs, such as cotters, brake shoes, shoe keys, nuts, etc. The procedure of preparing these billing repair cards is, in many instances, unnecessary and can be greatly simplified. I feel certain the solution of the problem can be made after an investigation has been completed to develop the facts in order to arrive at proper conclusions.

The average cost per car repaired and per car day for repairs made in train yards and classification yards in certain roads' bills is approximately the same, as shown in Table I.

In fact, all of the charges in the Interchange Rules are based on averages, therefore, it seems fair to assume that it would also be possible to arrive at an average allowance for the very light repairs that are being made in the train yards and classification yards.

Only recently the Interchange Rules were amended to provide charges against car owners for nuts and cotters applied. I am assuming this was done because certain railroads or companies were neglecting these items. But I feel sure that any railroad that might be guilty of such neglect would not be inclined to rectify conditions in this respect simply because their car repair bills might be increased by charges for fifty cotters per month at ten cents per cotted, or \$5.

When there is no penalty for neglect some will take a chance, but assess a penalty and then results will be forthcoming. Interchange rules are not prepared on the basis of penalties, but if there is neglect, then a penalty is the only way to overcome it.

Some will say this subject, that is, the discontinuance of billing, has been previously considered, therefore, there is no further action to be taken at this time. The subject should be studied from the viewpoint of discontinuing billing for only such train-yard and classification-yard repairs as I am now advocating.

I realize this same thought would not work out equitably in so far as shop or branch repairs are concerned because some railroads and companies have a regular maintenance program, others medium and others deferred, therefore, for that reason I consider that billing for work performed in shops and on repair branches should be continued.

However, I think the subject is worthy of considerable thought, keeping in mind the severe conditions under which train yard and classification yard billing repair cards are prepared. The discussion, therefore, should be on the idea rather than the method of settlement. The method of settlement can be decided after the necessary facts have been obtained. I estimate that if the idea were found practical it would eliminate the preparation of approximately 6,000,000 billing repair cards per year for bills rendered, or it would eliminate the handling of approximately 12,000,000 such repair cards per year considering both bills rendered and bills received.

Should Handling Line or Car Owner Be Responsible for Cut Journals?

Some contend that slid flat wheels and cut journals should be car owners' responsibility instead of handling line responsibility. Recommendations to that effect have been previously made which were not approved, no doubt, for good and sufficient reasons. If the reasons for not approving such recommendations still hold good today, then a special investigation should be conducted to determine the reason for the wide difference in performance on cars of different ownership. To make this more clear I will make mention of a few comparisons which I understand exist.

In a thirty-day period, Road A found it necessary to change 224 pairs of wheels on Road B cars account of

cut journals, whereas in the same period Road B found it necessary to change only 70 pairs on Road A cars on account of cut journals, a difference of 154 pairs in that short period, car days representing a ratio of $1\frac{1}{4}$ to 1. The average cost to change wheels account of cut journals amounts to approximately \$10 per pair. The difference referred to means that Road A lost about \$1,540 per month in repairing Road B cars, or a loss of about \$18,480 per year.

As a result of such differences I estimate that some railroads are losing approximately \$50,000 per year.

Surely there must be a reason for this difference in performance and just what it is, I believe, could be de-

Table I — Average Cost of Making Repairs in Train Yards and Classification Yards

Roads	Percent of train yard repair cards to total repair cards	Average cost per car repaired in train or class. yards	Average cost per car day for repairs made in train or class. yards
Road A vs. road 1...	55	\$0.56	\$0.015
Road A vs. road 2...	56	0.54	0.013
Road A vs. road 3...	58	0.52	0.012
Road A vs. road 4...	59	0.46	0.017
Road A vs. road 5...	62	0.60	0.012
Road A vs. road 6...	62	0.54	0.016
Road A vs. road 7...	62	0.50	0.017
Road A vs. road 8...	65	0.46	0.017
Road A vs. road 9...	66	0.67	0.014

veloped through an investigation by those thoroughly acquainted with that phase of car performance. This is the first step that should be taken. The result of such investigation would then permit proper consideration being given as to whether the responsibility for these defects should or should not be changed.

Should Cardable Damage Limits Be Revised and Defect Carding for Certain Wrong Repairs Be Discontinued?

I understand that Road T issues, or has issued against it, about 21,000 defect cards per year for cardable damage and wrong repairs, which means about 1,750 defect cards per month.

If that understanding is correct, then an investigation will disclose that too much time is being expended by both shop inspectors and interchange inspectors in preparing defect cards and attaching them to cars and in noting or recording them at interchange points, as the cars pass through interchange, when the time could be better utilized by such employees in making closer inspection for safety.

With reference to the number of defect cards that are issued and not used as authority to bill, about 6,200 or 55 per cent of all defect cards issued per year by or against Road T for Rule 32 damage and wrong repairs on foreign railroad owned cars and private car line cars, excluding owned cars, are not used for billing, the separation being as follows: 1,960 defect cards per year or 32 per cent covering Rule 32 damages are not used for billing and 4,240 defect cards per year or 68 per cent covering wrong repairs not used for billing.

The figures and percentages given in Table II will also tend to convey the thought that the limits for cardable damage are not sufficiently severe.

The question would naturally arise as to what can be done to better existing conditions. There is no question but what many different suggestions would be offered. One thought that could be advanced is to have the extent of damage as the governing factor so that the charges when billed would exceed \$10 per defect card. If this were done it would eliminate the necessity of Road T issuing approximately 15,000 defect cards per year,

without considering all of the other railroads. If this suggestion were followed, it is possible that it would eliminate close to 150,000 defect cards per year or 12,500 per month or 400 per day for all railroads in the United States and Canada without causing any hardship to any railroad or company.

Further, it would clear the cars of defect cards and the few defect cards that would be issued for the more extensive damage would not be on the cars for any

Table II—Extent of Charges Billed on Authority of Defect Cards Issued by or against Road T Covering Rule 32 Damage and Wrong Repairs on Foreign Railroad Cars and Private Line Cars

	Rule 32 damage		Wrong repairs	
	Number defect cards	Percent	Number defect cards	Percent
Charge less than \$1 per card.	480	11	200	12
Charge \$1 to \$3 per card...	1,100	26	200	44
Charge \$3 to \$5 per card...	560	13	400	24
Charge \$5 to \$10 per card...	700	16	260	16
Charge \$10 to \$50 per card..	920	22	60	4
Charge \$50 to \$100 per card.	240	6	None	..
Charge \$100 or over per card	240	6	None	..
Total	4,240	100	1,660	100

length of time, as those cars would be damaged to such extent that immediate repairs would be required if the car owner desired such cars to remain in service.

Some will say that the present practice of defect carding should not be discontinued because it will place a hardship on car owner; others may argue that more defect cards should be issued for car owner's protection than are now issued, and others might approve of the elimination of defect cards to a large extent. Therefore, it is anybody's guess as to what should be done and it would be difficult to draw proper conclusions until an investigation has been made to develop the facts.

In the absence of facts, some may contend that damage, regardless of how it occurred, should be considered car owner's responsibility on the basis that the handling line exercised all possible care in handling and they had no control over unusual occurrences. Others may contend that the extent of damage rather than the cause of damage should be the governing factor in the issuance of defect cards and that car owner should be responsible for all rake damage up to the point where the framework of the car is damaged, such as sills, posts, braces and plates, and others may contend that the present limits for unfair usage damage should be increased to such extent that the car would be immediately shopped and thus prevent defect cards from remaining on cars with slight damage until such time as a car owner elects to have repairs made.

Therefore, in view of the large number of defect cards issued covering wrong repairs and minor Rule 32 damage that are not being used for billing, also considering the number of days which elapse between date of defect cards and date of repairs, should a study be made with a view of ascertaining whether it would be practical to greatly reduce the number of such cards issued in order to lessen inspectors' clerical work and thus give them more time to devote to inspection for safety?

Should Correspondence and Investigations Account of Unavoidable Errors Be Reduced?

All billing clerks know of the large amount of correspondence and investigation that result from ordinary errors such as wrong car numbers and errors in pricing repair cards. In the majority of cases where wrong car numbers are involved, investigation discloses a correction in the car number is in order and, therefore, there

would be no adjustment. Errors in pricing repair cards are usually due to the large volume of such work performed. In most cases errors in pricing do not total to a large amount, or the amount of over-charges is reduced considerably by the amount of under-charges. Perhaps it would be more economical to all railroads and companies if an arbitrary allowance were made for them, in place of permitting exceptions to be taken to small over-charges or under-charges, or wrong car numbers.

With a view of reducing correspondence and investigations, and believing it would not result in a hardship on any railroad or company, I would offer for discussion the proposition of considering car repair bills correct as rendered when 99.5 per cent correct. In other words, disregard incorrectness due to the extent of one-half of one per cent of the total amount of bill for the unavoidable errors mentioned above.

To explain further, do not permit the billed road to take exceptions to charges unless the net overcharge or net undercharge exceeds one-half of one per cent of the total amount of bill and then only to adjust for an amount in excess of that allowance.

This would mean that when a \$1,000 bill was rendered the permissible allowance for all incorrectness would be \$5. In the event the net overcharge or undercharge amounted to \$12, then an adjustment of only \$7 would be in order. I am of the opinion this will reduce exceptions, letters and investigations about 90 per cent. If such a proposition would meet with approval, Rule 91 could be modified accordingly.

Should Car Repair Bills, Both Incoming and Outgoing, Be Analyzed to Prevent the Possibility of Specializing?

Sometimes it would be more advantageous to all concerned if billing clerks were instructed to analyze both incoming and outgoing car repair bills to ascertain whether conditions appear normal in so far as the number of items applied is concerned, instead of utilizing all of their valuable time in checking the billing repair cards and billing statements for correctness of labor and material prices and footings.

At least that is our thought and we have placed that system in effect in our Billing Bureau.

We have been and are now analyzing car repair bills

Table III — Comparison of Repairs Made by Roads A and B

	Item ratio	Car-day ratio
Truck-spring shims	506 to 33	15 to 1
Box lids	336 to 30	11 to 1
Brake beams	317 to 27	12 to 1
Air hose	283 to 21	13 to 1
Couplers	145 to 5	29 to 1
Knuckles	112 to 1	112 to 1
Brake-shafts repaired	86 to 5	17 to 1
Truck spring seats	63 to 1	63 to 1
Knuckle pins	66 to 2	33 to 1

by roads, by stations, by items, and by charges. Needless to say, some very peculiar conditions were noted in both the incoming and outgoing bills. I would not say that "stand-out" cases always represent wrong or improper practices, as investigation in most cases will disclose that the condition which appeared questionable can be explained, but such a check has the effect of letting those involved know that the situation is being watched, and by this method of procedure all foreign railroads and companies will receive the protection to which they are justly entitled.

As an example, Road A found it necessary in a period of 30 days to apply 1,362 cotters to Road B cars, where-

as in the same period Road B found it necessary to apply only 136 coppers to Road A cars, a difference of 1,226 coppers. Since the number of car days were equal, the car-day ratio is 1 to 1. Other such examples are given in Table III.

Should Rule 9 Be Modified by Reason of Interpretation (1) of Rule 70 Ruling on Charges for Wheel Renewals?

Interpretation (1) of Rule 70 provides that when wrought-steel wheels are applied in place of wrought-steel wheels removed to a car that is not stenciled to show type of wheels standard to it, cast-iron wheels shall be considered as standard to such car and the value of the wrought-steel wheels applied shall not exceed the value of new cast-iron wheels.

Some railroads are taking exception to charges, when wrought-steel wheels are applied in place of wrought-steel wheels removed, contending that car was not stenciled showing wrought-steel wheels standard, although they admit that their cars have mixed wheels under them, and they are requesting adjustment which amounts in some cases to \$40 per pair. They further contend that it is necessary for the repairing line to make notation on billing repair cards when car is stenciled for wrought-steel wheels, otherwise the charge will not be accepted when it exceeds the value of new cast-iron wheels.

Investigation disclosed that in some of the cases now in controversy the car was equipped with four pairs of wrought-steel wheels, yet car owner states that fact has no bearing on the permissible charge, as interpretation (1) of Rule 70 is very clear in this respect.

Car owner also has declined to furnish joint evidence in such cases showing whether or not car was stenciled, claiming the Interchange Rules never contemplated that the burden of proof, in such cases, be placed on car owner, and that it is an obligation of the repairing road to make necessary notation on billing repair cards, which, if done, would make the matter clear to all concerned.

Therefore, in view of the complications arising on this phase of car repair billing, should Rule 9 or Interpretation (1) of Rule 70 be modified so it will be clear to all concerned whether car owner must protect the situation through joint evidence, or whether the repairing road must make notation on billing repair card as to the stenciling on car for information of car owner.

Questions and Answers On the AB Brake

Operation of the Equipment

121—*Q.—What ports open in emergency, second stage?* A.—The same as in the first stage, except that the flow of air from the combined auxiliary and emergency reservoirs is restricted to the opening in the delay choke due to the fact that the in-shot valve is now seated.

122—*Q.—What ports open in emergency, third stage?* A.—The same ports are open in this stage, as in the second stage, with the following exceptions: An additional flow of air to the brake cylinder is now obtained via the timing valve and the timing choke. As the quick-action-chamber pressure has been reducing through the vent-piston choke, the vent-valve spring eventually forces the vent valve to its seat, closing communication between the brake pipe and the atmosphere.

123—*Q.—What ports open in release after emergency?* A.—In release after emergency the following ports are

open: Brake pipe to the quick-action chamber via the charging choke; brake pipe to accelerated-release check, vent-valve chamber and by-pass checks; auxiliary reservoir to brake cylinder via the in-shot valve; auxiliary reservoir to the release-insuring valve and duplex release-valve check; the quick-action chamber to the accelerated-release piston chamber; the in-shot piston volume to the inshot piston chamber; the emergency reservoir to the duplex release-valve check, spill-over check, and strut diaphragm.

124—*Q.—What ports open in accelerated-emergency release?* A.—In accelerated-emergency release the following ports are open: The brake pipe to the quick-action chamber via the charging choke, and also to the by-pass checks; the combined auxiliary-reservoir and brake-cylinder pressures to the brake pipe via the accelerated-release check valve; the quick-action chamber to the accelerated-release piston chamber; the in-shot-piston volume to the in-shot-piston chamber; the auxiliary reservoir to the release-insuring valve and to the duplex release-valve check; and the emergency reservoir to the spill-over check and the strut diaphragm and to the duplex release-valve check.

125—*Q.—At what stage does either the release or application by-pass check valves function?* A.—The release check valve opens to allow the brake-pipe air to flow to the face of the service piston when releasing, and the application check valve opens to allow the brake-pipe pressure to flow from the face of the service piston when applying the brake, upon the development of approximately 2 lb. difference in pressure across the strainer.

126—*Q.—What would cause this difference in pressure?* A.—The hair strainer becoming clogged with dirt.

127—*Q.—Does the emergency-reservoir pressure vary when the service slide valve assumes release position?* A.—Yes.

128—*Q.—Why?* A.—Communication is established to the auxiliary reservoir.

129—*Q.—What is the advantage of this feature?* A.—It provides a quick recharge of the auxiliary reservoir, and a more prompt and positive release.

130—*Q.—What assurance have we of a positive release in case of excessive friction of the operating parts?* A.—The release-insuring valve functions to accomplish a release.

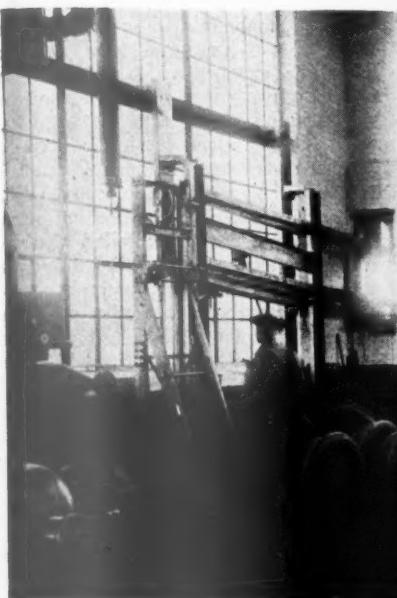
131—*Q.—How is this accomplished?* A.—When the brake-pipe pressure on the left of the release-insuring diaphragm exceeds by $1\frac{1}{2}$ lb. the auxiliary-reservoir pressure on the right, the diaphragm will be deflected to the right, unseating the release-insuring valve. This movement connects the auxiliary-reservoir pressure to the atmosphere via the release-insuring choke, the cavity in service slide valve and the retaining valve.

132—*Q.—How long does the reduction of the auxiliary reservoir pressure continue?* A.—Until sufficient differential is created across the service piston to move it and the slide valve to release and charging position.

133—*Q.—How does this prevent excessive reduction of auxiliary-reservoir pressure?* A.—The service slide valve, in moving to release, cuts off communication to the atmosphere.

134—*Q.—With the quick-action chamber uncharged, what provision is made to prevent the emergency slide valve from unseating, in view of the fact that emergency-reservoir pressure is the lower?* A.—The slide valve is balanced by a spring-and-diaphragm-loaded strut. The emergency reservoir is connected to the upper side of the diaphragm, exerting pressure in a downward direction, thereby holding the slide valve on its seat.

Modern wheel shop (below) with inclined runways for moving scrap wheels and axles out of the shop



Inclined runway (above) and short sections of hinged angle used in diverting wheels to the desired scrap bins

Save Labor In Wheel Handling

One of the modern wheel shops of the Middle West is that of the Illinois Central at Markham, Ill., where wheel and axle work for the northern lines of this road is handled. One of the features of this shop, which is well equipped with axle lathes, boring mills, a heavy-duty wheel lathe, wheel presses and a Norton car-wheel grinding machine, is the provision for a minimum of manual labor in handling wheels and axles.

Mounted wheels and axles received at this shop from Freeport, Ill., Clinton and the Chicago terminal are unloaded by clam shell from the wheel car to inclined tracks on which the wheels roll into the shop through the door illustrated. Wheels are dismounted in a double-acting press and rolled one at a time to the elevator and inclined runway shown at the left in the lower illustration. Passing through the hole in the shop wall, the wheels roll down the incline shown in the upper illustration, being diverted into the proper scrap bin by a short piece of hinged angle section. These wheels are loaded by means of a magnet from the bin into a scrap car for subsequent sale as scrap.

Axles are placed by means of a monorail hoist on an axle carriage, as shown at the right in the lower illustration. This carriage also operates through the shop wall and down an inclined track, being controlled, however, by an electrically operated endless cable which moves the carriage up and down the runway. A large handwheel is used to trip the carriage opposite the proper pile of stored axles onto which the axle rolls clear. The endless cable then is used to bring the carriage back into the shop, ready for the next axle. All operations of moving the carriage and tripping the axle are controlled

by one man from a station at the handwheel shown in the illustration.

Scrap wheels and axles only are sent out of the shop, the others being moved by monorail to designated positions within the shop where necessary conditioning operations are performed to fit the wheels and axles for further service. With this method of handling, 100 pairs of wheels are dismounted and the scrap wheels and axles moved to appropriate scrap piles or bins by three men in eight hours.

* * *



Taking three dimensional colored movies of the making of valves in the factory of the Hancock Valve Division of the Consolidated Ashcroft-Hancock Company—A method incorporating a number of the first experimental stereoscopic industrial shots in full color, made possible by the employment of Polaroid glass, will be on exhibit at the New York Museum of Science and Industry for several months

Among the Clubs and Associations

PURCHASES AND STORES DIVISION, A. A. R.—The Purchases and Stores Division, Association of American Railroads, has selected June 21, 22 and 23 as the dates for its three-day annual meeting to be held at Atlantic City, N. J. Thus the sessions will coincide with the annual meeting of the Mechanical Division, A.A.R., and the exhibit of the Railway Supply Manufacturers Association.

MECHANICAL DIVISION, A. A. R.—According to a recent circular regarding the annual meeting of the Association of American Railroads, Mechanical Division, which will be held in Atlantic City, N. J., June 16 to 23, inclusive, the reports of committees investigating locomotive matters will be received and discussed Wednesday, Thursday and Friday, June 16 to 18, inclusive, and reports of committees investigating car matters will be received and discussed Monday, Tuesday and Wednesday, June 21 to 23, inclusive.

CANADIAN RAILWAY CLUB.—L. W. Wallace, director of the Equipment Research Division of the Association of American Railroads, will be the speaker at the meeting of the Canadian Railway Club at 8:15 p.m. on March 8 at the Windsor Hotel, Montreal.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB.—John M. Hall, chief inspector Bureau of Locomotive Inspection, Interstate Commerce Commission, will reminisce on twenty-five years of federal inspection of locomotives at the March 18 meeting of the Southern and Southwestern Railway Club, which will be held at 10 a.m. at the Ansley Hotel, Atlanta, Ga.

NEW ENGLAND RAILROAD CLUB.—The annual meeting, election of officers, etc., of the New England Railroad Club will be held at the Hotel Touraine, Boston, Mass., on March 9, following dinner at 6:30 p.m. Following the business session the construction, etc., of the San Francisco-Oakland Bay bridge will be shown in moving pictures.

CENTRAL RAILWAY CLUB OF BUFFALO.—"Steel Castings in High-Speed Railroading" will be the subject discussed by William M. Sheehan, manager, eastern district sales, General Steel Castings Corporation, before the meeting of the Central Railway Club of Buffalo at 8 p.m. on March 11 at the Hotel Statler, Buffalo, N. Y.

WESTERN RAILWAY CLUB.—The March 17 meeting of the Western Railway Club will be Engineering Night. Following dinner at 7 p.m. in the Grand Ballroom of the Hotel LaSalle, Chicago, Dr. Arthur N. Talbot, professor emeritus of the University of Illinois and chairman of the A.R.E.A. Special Committee on Stresses in Railroad Track, will discuss the Relation between Track and Rolling Stock.

Club Papers

Notes on Locomotive Testing with a Glance at History

Railway Club of Pittsburgh.—Meeting held at Pittsburgh, Pa., December 17, 1936. Subject, Notes on Locomotive Testing with a Glance at history, by Lawford H. Fry, Railway Engineer, Edgewater Steel Company. Mr. Fry reviewed early nineteenth century locomotive tests and test procedures and quoted contemporary accounts of first runs made by early locomotives. The later portion of the paper deals mostly with test plants, giving the background of the development of the plants, their location and some of the results obtained from their use. ¶ Mr. Fry stated that the steam locomotive has been the subject of tests for over 100 years but that there is still disagreement over many basic facts which could and should be settled by existing test data. As a matter of background, the paper reviewed the history of George Stephenson's "Rocket." In discussing early American locomotive trials, Mr. Fry mentioned the trial run made by Horatio Allen on August 8, 1829, with the "Stourbridge Lion" at Honesdale, Pa. Another historical locomotive trial was made with the "Best Friend" on the South Carolina Railway in December 1830. This was the first locomotive built in America for actual service on a railroad. Its designer was E. L. Miller of Charleston, South Carolina, who attended the trials on the Liverpool and Manches-

ter Railway the year before. Mr. Fry mentioned "A Practical Treatise on Locomotive Engines," a book published in France in 1834 by Count F. M. G. De Pambour, who conducted a large number of locomotive tests and described them in his book. Pambour made exhaustive practical tests and measured train resistance, studied the evaporative capacity of various locomotive boilers and set up formulas for computing the dimensions of a locomotive for any given service. ¶ Since that day there have been innumerable tests of locomotives on which locomotive design have been based. Mr. Fry did not attempt to give a complete and detailed history of locomotive testing. He pointed out that locomotive tests can be made by one of the following three methods: (1) Road tests with regular trains, (2) road tests at constant speed and cut-off, and (3) tests on a stationary locomotive testing plant. ¶ Discussing the first of these, Mr. Fry stated that road tests with regular trains are useful mainly to check the performance of a given locomotive. They serve to measure coal and water consumption, to examine the relation between train loads and timing, and to check tonnage-rating assignments. Because it is not usually possible with these tests to obtain accurate information regarding such individual processes as combustion, steam production, and utilization of steam, Mr. Fry stated that they did not provide information necessary to make a scientific study of locomotive design. To obtain information for this purpose a locomotive must be run under constant conditions of speed and cut-off for a considerable length of time. These tests can be made on the road under special conditions, or at a locomotive testing plant. ¶ Road tests of this type have been used rather successfully in Russia, France and Germany and are made with an auxiliary locomotive used to pull or brake the test locomotive as needed. Also a further advance mentioned by Mr. Fry in this type of testing includes the use of a dynamometer car and a test train of one or more brake locomotives. Results obtained with this type of test are comparable with those obtained on a stationary plant. ¶ Discussing the locomotive testing plant, Mr. Fry called attention to the first large scale testing plant which was built by the Pennsylvania Railroad and exhibited at the St. Louis exhibition in 1904. He also dealt with the locomotive testing plants designed and erected by Dr. W. F. M. Goss at Purdue University. The first plant was destroyed by fire in 1894. Tests on the second plant threw light on the factors limiting horsepower and rates of combustion which were not well understood before the test-plant results were available. Cylinder action was investigated, and work done on locomotive front-ends influenced American locomotive practice for many years. ¶ The author recalled that the locomotive testing plant set up



A tourist train on a 30-in gage Austrian railroad which penetrates about 40 miles into the winding valley of the Ybbs river

at the University of Illinois in 1914 was the third to be built in this country. As a matter of historical record Mr. Fry mentioned the early crude plant built in Russia in 1896; the French plant at Vitry, built in 1933, which is used by the seven large railway systems of France, and two small American plants installed by the Chicago & North Western in 1894 and Columbia University in 1899, respectively, both of which were later abandoned. Mr. Fry also mentioned the German plant at Gruenwald, Germany, which was placed in operation in 1930. ¶ Mr. Fry's paper was discussed by Professor L. E. Endsley, who at one time was in charge of the Purdue locomotive testing plant. He discussed the locomotive used at the plant, and researches made with it on front-ends and superheaters. ¶ Mr. Fry closed the discussion by referring to the number of different locomotive designs tried out in Europe.

DIRECTORY

The following list gives names of secretaries, dates of next regular meetings, and places of meetings of mechanical associations and railroad clubs:

AIR-BRAKE ASSOCIATION.—T. L. Burton, care of Westinghouse Air Brake Company, 3400 Empire State Building, New York.

ALLIED RAILWAY SUPPLY ASSOCIATION.—F. W. Venton, Crane Company, Chicago.

AMERICAN RAILWAY TOOL FOREMEN'S ASSOCIATION.—G. G. Macina, 11402 Calumet avenue, Chicago.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—C. E. Davies, 29 West Thirty-ninth street, New York.

RAILROAD DIVISION.—Marion B. Richardson, 21 Hazel avenue, Livingston, N. J.

MACHINE SHOP PRACTICE DIVISION.—G. F. Nordenholz, 330 West Forty-second street, New York.

MATERIALS HANDLING DIVISION.—F. J. Shepard, Jr., Lewis-Shepard Co., Watertown Station, Boston, Mass.

OIL AND GAS POWER DIVISION.—M. J. Reed, 2 West Forty-fifth street, New York.

FUELS DIVISION.—W. G. Christy, Department of Health Regulation, Court House, Jersey City, N. J.

ASSOCIATION OF AMERICAN RAILROADS.—J. M. Symes, vice-president operations and maintenance department, Transportation Building, Washington, D. C.

DIVISION I.—OPERATING.—SAFETY SECTION.—J. C. Caviston, 30 Vesey street, New York.

DIVISION V.—MECHANICAL.—V. R. Hawthorne, 59 East Van Buren street, Chicago. 1937 convention, June 16-23, Atlantic City, N. J.

COMMITTEE ON RESEARCH.—E. B. Hall, chairman, care of Chicago & North Western, Chicago.

DIVISION VI.—PURCHASES AND STORES.—W. J. Farrell, 30 Vesey street, New York. Annual meeting, June 21, 22 and 23, Atlantic City, N. J.

DIVISION VIII.—MOTOR TRANSPORT.—CAR SERVICE DIVISION.—C. A. Buch, Transportation Building, Washington, D. C.

ASSOCIATION OF RAILWAY ELECTRICAL ENGINEERS.—Jos. A. Andreuccetti, C. & N. W., 1519 Daily News Building, 400 West Madison street, Chicago, Ill.

CANADIAN RAILWAY CLUB.—C. R. Crook, 2271 Wilson avenue, Montreal, Que. Regular meetings, second Monday of each month, except in June, July and August, at Windsor Hotel, Montreal, Que.

CAR DEPARTMENT OFFICERS' ASSOCIATION.—A. S. Sternberg, master car builder, Belt Railway of Chicago, 7926 South Morgan street, Chicago.

CAR FOREMEN'S ASSOCIATION OF CHICAGO.—G. K. Oliver, 2514 West Fifty-fifth street, Chicago. Regular meetings, second Monday in each month, except June, July and August, La Salle Hotel, Chicago.

CAR FOREMEN'S ASSOCIATION OF OMAHA, COUNCIL BLUFFS AND SOUTH OMAHA INTERCHANGE.—H. E. Moran, Chicago Great Western, Council Bluffs, Ia. Regular meetings, second Thursday of each month at 1:15 p. m.

CENTRAL RAILWAY CLUB OF BUFFALO.—Mrs. M. D. Reed, Room 1817, Hotel Statler, Buffalo, N. Y. Regular meetings, second Thursday each month, except June, July and August, at Hotel Statler, Buffalo.

EASTERN CAR FOREMEN'S ASSOCIATION.—E. L. Brown, care of the Baltimore & Ohio, St. George, Staten Island, N. Y. Regular meetings, fourth Friday of each month, except June, July, August and September.

INDIANAPOLIS CAR INSPECTION ASSOCIATION.—R. A. Singleton, 822 Big Four Building, Indianapolis, Ind. Regular meetings, first Monday of each month, except July, August and September, at Hotel Severin, Indianapolis, at 7 p. m.

INTERNATIONAL RAILWAY FUEL ASSOCIATION.—See Railway Fuel and Traveling Engineers' Association.

INTERNATIONAL RAILWAY GENERAL FOREMEN'S ASSOCIATION.—William Hall, 1061 West Washington street, Winona, Minn. Next meeting, September 28 and 29, Hotel Sherman, Chicago, Ill.

INTERNATIONAL RAILWAY MASTER BLACKSMITHS' ASSOCIATION.—W. J. Mayer, Michigan Central, 2347 Clark avenue, Detroit, Mich.

MASTER BOILER MAKERS' ASSOCIATION.—A. F. Stiglmeier, secretary, 29 Parkwood street, Albany, N. Y.

NEW ENGLAND RAILROAD CLUB.—W. E. Cade, Jr., 683 Atlantic avenue, Boston, Mass. Regular meetings, second Tuesday in each month, except June, July, August and September, at Hotel Touraine, Boston.

NEW YORK RAILROAD CLUB.—D. W. Pye, Room 527, 30 Church street, New York. Meetings, third Friday in each month, except June, July, August and September, at 29 West Thirty-ninth street, New York.

NORTHWEST CAR MEN'S ASSOCIATION.—E. N. Myers, chief interchange inspector, Minnesota Transfer Railway, St. Paul, Minn. Meetings, first Monday each month, except June, July and August, at Midway Club rooms, University and Prior avenue, St. Paul.

PACIFIC RAILWAY CLUB.—William S. Wollner, P. O. Box 3275, San Francisco, Cal. Regular meetings, second Thursday of each month in San Francisco and Oakland, Cal., alternately—June in Los Angeles and October in Sacramento.

RAILWAY CLUB OF GREENVILLE.—J. Howard Waite, 43 Chambers avenue, Greenville, Pa. Regular meetings, third Thursday in month, except June, July and August.

RAILWAY CLUB OF PITTSBURGH.—J. D. Conway, 1941 Oliver Building, Pittsburgh, Pa. Regular meetings, fourth Thursday in month, except June, July and August, Fort Pitt Hotel, Pittsburgh, Pa.

RAILWAY FIRE PROTECTION ASSOCIATION.—R. R. Hackett, Baltimore & Ohio, Baltimore, Md.

RAILWAY FUEL AND TRAVELING ENGINEERS' ASSOCIATION.—T. Duff Smith, 1255 Old Colony building, Chicago. Annual meeting, with exhibits, Hotel Sherman, Chicago, September 28, 29, 30.

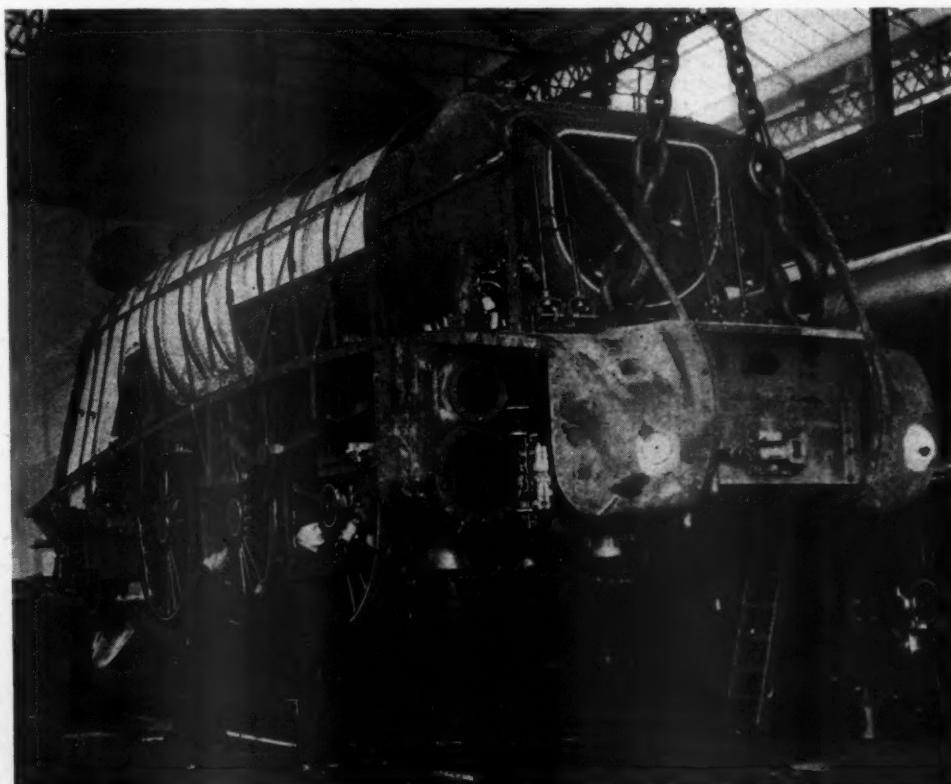
RAILWAY SUPPLY MANUFACTURERS' ASSOCIATION.—J. D. Conway, 1941 Oliver Building, Pittsburgh, Pa. Meets with Mechanical Division and Purchases and Stores Division, Association of American Railroads. Exhibit June 16 to 23, inclusive, Atlantic City, N. J.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB.—A. T. Miller, P. O. Box 1205, Atlanta, Ga. Regular meetings, third Thursday in January, March, May, July and September. Annual meeting, third Thursday in November, Ansley Hotel, Atlanta, Ga.

TORONTO RAILWAY CLUB.—R. H. Burgess, Box 8, Terminal A, Toronto, Ont. Meetings, fourth Monday of each month, except June, July and August, at Royal York Hotel, Toronto, Ont.

TRAVELING ENGINEERS' ASSOCIATION.—See Railway Fuel and Traveling Engineers' Association.

WESTERN RAILWAY CLUB.—C. L. Emerson, executive secretary, 822 Straus Building, Chicago. Regular meetings, third Monday in each month, except June, July, August and September.



Lifting a streamline locomotive after it had been wheeled at the Dorchester works of the London & North Eastern Railway



The "Golden Eagle," one of the locomotives which are to haul the Coronation express trains of the London & North Eastern between London and Edinburgh, lined up with two Silver Jubilee engines and a Pacific type locomotive during a demonstration

NEWS

Arch-Bar Truck Replacements

In a letter to all freight car owners dated February 6, and pertaining to transportation hazards due to arch-bar truck failures, the secretary of the A. A. R. Mechanical Division included a statement showing the extent of compliance with Interchange Rule 3, Sec. (t), Par. (4), which provides that arch-bar trucks will not be accepted in interchange after January 1, 1938. This statement indicates that on December 31, 1936, 487,203 cars, or 22.2 per cent of railroad and private freight cars, were equipped with arch-bar trucks. The total number of car owners involved is 385 and the total interchange freight equipment owned or controlled, 2,198,365 cars. The report showed that the total

number of interchange freight cars equipped with arch-bar trucks expected to be in service as of June 30, 1937, is 387,643.

One of the accompanying tables shows how the percentage of cars with arch-bar trucks has decreased each year from 44.2 per cent in 1929 to 22.2 per cent in 1936. The other table shows the number and percentage of railroad and private cars in interchange service equipped with cast-steel side frames, as compared to arch-bar trucks, as of December 31, 1936.

British Equipment Programs

BRITISH railways have authorized the construction during 1937 of 532 locomotives, 2,000 passenger-train cars and 34,000 freight cars. Included in the locomotive

total are 17 of streamline design, being constructed by the London & North Eastern to haul its new "Coronation" streamline trains between London and Edinburgh. Names of birds are to be given to these new locomotives, the first five being "Golden Eagle," "Falcon," "Merlin," "Kingfisher" and "Kestrel."

Streamliner Derailed

Two cars of the streamliner "City of Denver" of the Union Pacific-Chicago & North Western were derailed on February 8 when an axle broke near Orchard, Colo. After the accident the train continued to Denver, and, on the following day, made its trip to Chicago without the derailed (Continued on next left-hand page)

Comparative Yearly Statement of Railroad and Private Freight Cars Equipped with Arch Bar Trucks

	Dec. 31, 1929	Dec. 31, 1930	Dec. 31, 1931	Dec. 31, 1932	Dec. 31, 1933	June 30, 1934	Dec. 31, 1934	June 30, 1935	Dec. 31, 1935	June 30, 1936	Dec. 31, 1936
Total number of car owners ...	456	429	425	426	415	415	413	415	401	392	385
Total number of cars	2,823,613	2,835,881	2,757,049	2,677,441	2,545,625	2,485,241	2,410,723	2,352,958	2,281,214	2,226,886	2,198,365
Cars with arch bar trucks ...	1,248,530	1,156,058	1,065,674	1,000,654	902,357	848,354	782,464	734,799	664,676	589,445	487,203
Percentage with arch bar trucks	44.2	40.8	38.7	37.4	35.4	34.1	32.5	31.2	29.1	26.5	22.2

Recapitulation of Number and Percentage of Railroad and Private Cars in Interchange Service Equipped with Cast Steel Side Frames as Compared to Arch Bar Trucks, as of December 31, 1936

Per cent of cars equipped with side frames	Number, R.R. or P.C.L.	Total cars owned	Cars equipped with side frames		Cars equipped with arch bars		Decrease in AB truck ownership between 6-30-36 and 12-31-36	No. cars with AB trucks expected to be in service as of 6-30-37
			Number cars	Per cent	Number	Per cent		
100	65	98,085	98,085	100.0	137,324	10.2	41,405	100,867
75 to 100	122	1,344,913	1,207,589	89.8	152,504	33.5	41,476	108,098
50 to 75	79	455,315	302,811	66.5	192,316	65.2	18,465	173,929
0.1 to 50	87	294,993	102,677	34.8	5,059	100.0	/ 343	4,749
0.0	32	5,059	0	0.0	487,203	22.2	102,242	387,643
Totals	385	2,198,365	1,711,162	77.8				



ONE of the three Mikado Type Locomotives recently delivered by Lima Locomotive Works, Incorporated, to The Detroit & Toledo Shore Line Railroad Company.

LIMA LOCOMOTIVE WORKS, INCORPORATED, LIMA, OHIO



cars, an observation car and a sleeping car. At Chicago the newly constructed cars of the Pullman Company, the "Advance" and the "Forward," were added to the consist of the "City of Denver" and were used until a new axle had been placed in the truck of the derailed cars on February 10.

P. R. R. Program for Eliminating Arch-Bar Trucks

THE Pennsylvania's program for installing cast-steel side frames on its freight cars which are now equipped with arch-bar trucks is proceeding at a rate which will assure its completion by the end of this year. Thus, the Pennsylvania will have no freight cars equipped with arch-bar trucks on January 1, 1938, the date on which the Association of America Railroads' rule barring such cars from interchange becomes effective. The Pennsylvania's program involves the replacement of trucks under 185,000 cars.

Reverse-Gear Order Proposed to I. C. C.

THE principal railroads and the brotherhoods representing their engine employees reached an agreement on November 20 on a plan for the equipment of locomotives with power reverse gears. This contemplated the dismissal of the complaint which had been filed by the brotherhoods with the Interstate Commerce Commission, but W. P. Bartel, director of the commission's Bureau of Service, and H. C. King, special examiner, have recommended in a proposed report that the commission retain control of the subject by issuing an order requiring the roads to equip their lever-operated manual-reverse-gear-type locomotives of the classes and weights specified in the agreement (road engines weighing 150,000 lb. or more on drivers and switching engines weighing 130,000 lb. or more on drivers) with a suitable type of power-operated reverse gear.

The report says that as of August 1, 1935, it was shown that 27,587, or 58 per cent, of the locomotives owned by the Class I railroads were equipped with power reverse gear but that "we have no means of determining the total cost to the railroads of equipping the locomotives not now operated with power reverse gear with that device." The railroads had given an estimate of \$4,630,165 for 11,247 locomotives at \$411.68 per locomotive, while the complainants had given an estimate of \$2,643,045 for a cheaper type of gear.

In enjoining the previous order, held invalid because of the absence of the basic or essential findings as to whether the use of manual reverse gear as compared with power reverse gear "causes unnecessary peril to life or limb," the district court had found that the commission had failed to consider evidence as to the railroads' financial condition, so the proposed report considers it and reaches the conclusion that "no undue burden should be imposed on any railroad but that the record clearly indicates the desirability of equipping most of the locomotives operating under present-day conditions with modern reversing gear. In the long run power reverse gear is economical."

(Turn to next left-hand page)

New Equipment Orders and Inquiries Announced Since the Closing of the February Issue

LOCOMOTIVE ORDERS			Builder
Road	No. of locos.	Type of loco.	
Can. Pac.	30 ¹	4-6-4	Montreal Loco. Wks.
	20	F-1-a	Canadian Loco. Co.
C. & N. W.	8 ²	4-6-4	American Loco. Co.
E. J. & E.	6	Diesel-elec.	Electro-Motive Corp.
Mich. Limestone Co.	2	600-hp. Diesel switchers	
Pere Marquette	15	2-8-4	American Loco. Co.
	11	Tenders ³	Lima Loco. Wks.
Pickands, Mather & Co	1	0-8-0	American Loco. Co.
Santa Barbara-Vigia (Venezuela)	1	2-4-4 tank	Baldwin Loco. Wks.
LOCOMOTIVE INQUIRIES			Baldwin Loco. Wks.
Roberval & Saguenay	1	2-8-2	
FREIGHT CAR ORDERS			Builder
Road	No. of cars	Type of cars	
Can. Nat'l	1,000	Box	Eastern Car Co., Ltd.
	300	Gondola	
	175	Refrigerator	
	15	Snow plows	
	1,000	Box	National Steel Car Corp.
	1,000	Box	
	58	Flat	
	125	Refrigerator	
Can. Pac.	1,900	40-ton box	Canadian Car & Fdry. Co. Co. shops at Transcona, Man. Canadian Car & Fdry. Co.
	1,100	40-ton box	
	300	50-ton hopper	
	200	50-ton gondola	
	100	75-ton gondola	National Steel Car Corp.
Clinchfield	600	50-ton hopper	
	250	50-ton gondola	
	250	50-ton box	
C. & I. M.	100	Hopper	American Car & Fdry. Co. Greenville Steel Car Co. Pullman-Std. Car Mfg. Co.
C. & N. W.	100	Gondola	
	150	50-ton Rodger ballast	
Great Nor.	500	Box	American Car & Fdry. Co. American Car & Fdry. Co. Pullman-Std. Car Mfg. Co. Pressed Steel Car Co. Company shops
	500	Box	
	500	Gondolas	
Lehigh Valley	20	Caboose	
Louisville & Nashville	300	Maxend Hart Selective ballast	American Car & Fdry. Co.
	27	50-ton Hart Selective ballast	
	500	Hopper	
	500	Hopper	
Louisiana & Arkansas	400	Hopper	Bethlehem Steel Co. Mt. Vernon Car Mfg. Co. Pressed Steel Car Co. Pullman-Std. Car Mfg. Co. Pullman-Std. Car Mfg. Co. Company shops
M-K-T	800	Hopper	
	100	Box	
	500	Gondolas	
	500	Stock	American Car & Fdry. Co. American Car & Fdry. Co. Mt. Vernon Car Mfg. Co. Pressed Steel Car Co. Magor Car Corp. Company shops
	100	40-ton auto.	
	125	50-ton auto.	
	25 ⁴	50-ton auto.	
Mo. Pac.	500	55-ton twin hopper	American Car & Fdry. Co. American Car & Fdry. Co. Mt. Vernon Car Mfg. Co. Pressed Steel Car Co. Magor Car Corp. Company shops
	1,000	50-ton box	
	700	50-ton gondolas	
	25	Caboose	
	300	50-ton flat	Pressed Steel Car Co. Pullman-Std. Car Mfg. Co. Differential Steel Car Co.
Mexican Ry.	50	Box	
N. C. & St. L.	500	Box	
Phelps Dodge Corp.	30	30 cu. yd. dump	
FREIGHT-CAR INQUIRIES			
Central of Brazil	350	55-ton Gondola	
	150	55-ton box	
	250	28-ton gondola	
	150	20-ton box	
	100	Flat	
D. T. & I.	500	50-ton box	
	200	50-ton auto.	
	100	50-ton auto. with racks	
Grand Trunk Western	200	40-ton refrigerator	
	200	50-ton auto.	
Newburgh & South Shore	100	50-ton gondolas	
PASSENGER-CAR ORDERS			Builder
Road	Type of car	No. of cars	
C. & O.	3	Comb. pass. & bagg.	Bethlehem Steel Co.
C. B. & Q.	4 ⁵	Coaches	Edward G. Budd Mfg. Co.
Ill. Central	26 ⁶	Coach-dinette	American Car & Fdry. Co.
M-K-T	20	40-ton bagg-exp.	American Car & Fdry. Co.
	25	Chair	
	3	Dining	
	1	Lounge	
Sou. Pac.	41 ⁷	Pass.	Pullman-Std. Car Mfg. Co.
PASSENGER-CAR INQUIRIES			
Erie	80	Milk	

¹ These locomotives will have 275-lb. boiler pressure, and 45,000-lb. tractive force; five of the locomotives will be equipped with boosters.

² Purchase authorized by district court at Chicago. The locomotives are to be designed to haul 14 to 16 cars of standard weight at 120 m.p.h. Two will be used on the "400" between Chicago and the Twin Cities, and six on through trains between Chicago and Omaha.

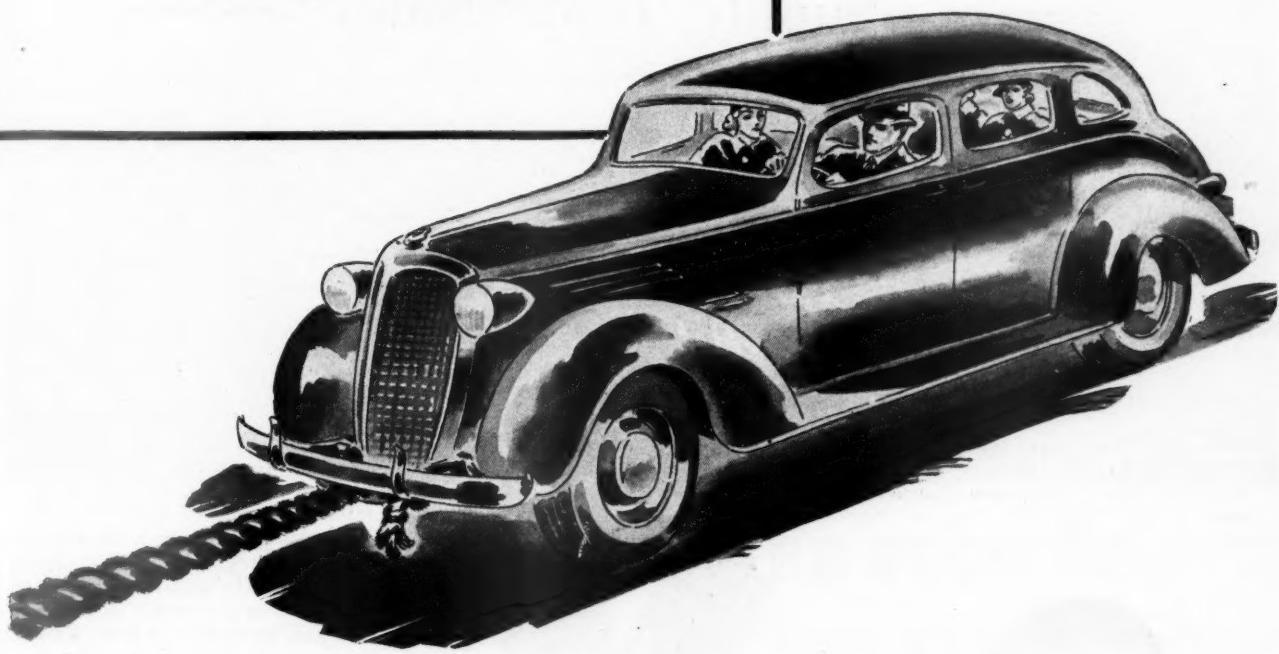
³ Each tender will have a capacity of 22 tons of coal and 22,000 gallons of water.

⁴ To be equipped with end doors.

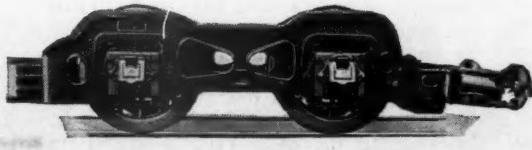
⁵ The 4 coaches will be used with conventional equipment operated on the "Fort Worth & Denver City" between Denver, Colo., Fort Worth, Tex., and Dallas. The 2 coach-dinette cars will be used in the "Twin Cities Zephyrs."

⁶ These cars are in addition to the 24 ordered last year for use in the new Daylight trains. Of the 41 cars, 25 are for general service and 16 are for the Sunbeam of the Texas & New Orleans.

You wouldn't
INTENTIONALLY
court failure



You don't take any chances in your automobile repair work—unless you have to. » » » When things wear, as they must in time, back to the seller you go for repairs. » » » In your locomotive replacement work, it is even more important that you use genuine replacement parts—in case of failure you can't just pull to the side of the road and get towed home—you hold up the railroad. » » » Genuine Franklin Replacement Parts for Franklin devices safeguard against expensive failure—but they also actually cost less per 1,000 engine miles, and save a lot of delay and headaches.



FRANKLIN RAILWAY SUPPLY CO., INC.



NEW YORK
CHICAGO
MONTREAL

Type AB Brake Installations

UNDER date of January 30, 1937, the secretary of the Mechanical Division, A. A. R., issued to all car owners the usual fourth quarterly statement showing the number of freight cars on which brake equipment has been converted to comply with the specifications for freight car air

Railroad Private Cars Equipped with Type AB Air Brakes—Report for Quarter Ending December 31, 1936

Number of car owners	401
Number of interchange freight cars owned as of December 31, 1936	2,200,303
Number of new interchange freight cars acquired during the quarter	19,472
Number of interchange freight cars converted during the quarter	3,676
Number of cars equipped with AB brakes as of September 30, 1936	86,762
Number of cars equipped with AB brakes as of December 31, 1936	109,796
Number of units retired, destroyed or otherwise disposed of during the quarter	37,175
Percentage of interchange freight cars equipped with AB brakes as of December 31, 1936	4.99

Comparative Quarterly Statement of Railroad and Private Cars Equipped with Type AB Air Brakes

	Mar. 31, 1935	June 30, 1935	Sept. 30, 1935	Dec. 31, 1935	Mar. 31, 1936	June 30, 1936	Sept. 30, 1936	Dec. 31, 1936
Total car owners	351	394	422	420	416	416	411	401
Int. frt. cars owned	2,337,716	2,338,480	2,330,021	2,283,681	2,242,691	2,230,506	2,219,775	2,200,303
Cars with AB brakes	27,571	31,546	35,920	46,842	53,499	66,361	86,763	109,796

Per cent with AB
brakes

1.18

1.35

1.54

2.05

2.39

2.98

3.91

4.99

brakes, adopted in 1933. One of the tables indicates that 109,796 railroad and private cars were equipped with Type AB brakes as of December 31, 1936, this being 4.99 per cent of all interchange freight cars. The other table shows how this percentage has increased each quarter since March 31, 1935, when it was 1.18 per cent.

Supply Trade Notes

THE PRESSED STEEL CAR COMPANY, INC., has moved its New York office from 80 Broad street to 230 Park avenue.

R. D. BARTLETT, assistant to the president of the Chicago Railway Equipment Company, Chicago, has been promoted to vice-president in charge of manufacture.

THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, about May 1, will move its Pittsburgh, Pa., office and some of its general offices now located at East Pittsburgh, to the Union National Bank building in Pittsburgh.

CLEON M. HANNAFORD, who has been appointed sales engineer, western territory, of the Wine Railway Appliance Company, as noted in the January 9 issue of the Railway Age, page 133, was born in Marlboro, N. H., on March 6, 1891. In 1913



Cleon M. Hannaford

he became a blue-print operator in the employ of the Boston & Albany, later serving as tracer and then draftsman in the mechanical department. On January 1, 1917, he became a draftsman in the mechanical department of the Chesapeake & Ohio at Richmond, Va., resigning in 1922 to enter the railway supply business as president of the Car Devices Company, Inc., at Richmond. Mr. Hannaford is now sales engineer, western territory, of the Wine Railway Appliance Company and

the Unitcast Company, with headquarters at Toledo, Ohio.

MUSCOE BURNETT, JR., assistant sales manager of The Oxweld Railroad Service Company, Chicago, has been appointed sales manager. Mr. Burnett was born at Paducah, Ky., and was educated at the



Muscoe Burnett, Jr.

University of Virginia. Since leaving college in 1920, he has been associated continuously with various units of the Union Carbide & Carbon Corporation, of which The Oxweld Railroad Service Company is one. His first connection in 1920 was with The Oxweld Acetylene Company. Four years later he was transferred to the export department of the Union Carbide Company, later going to the Linde Air Products Company as assistant division manager at Chicago. He held the latter position until October, 1935, when he was appointed assistant sales manager of The Oxweld Railroad Service Company.

DANIEL J. SAUNDERS has been appointed manager of railway and industrial sales of the Permutit Company with headquarters at its main office in New York City.

G. O. HAUSKINS has entered the employ of the Peerless Equipment Company, assigned to the sales department, in its New York office. Mr. Hauskins was formerly with the Mt. Vernon Car Mfg. Co.

Obituary

HENRY E. SHELDON, president and founder of the Allegheny Steel Company, Brackenbridge, Pa., died at his home in Pittsburgh, Pa., on February 10, at the age of 75 years. In 1932, Mr. Sheldon announced a new metallurgical development permitting ordinary carbon steel to be clad with stainless steel.

EDWARD M. SEXTON, railroad sales manager of Air Reduction Sales Company, died on February 15, in New York, after an illness of several weeks. He was 56 years old. Mr. Sexton was born on Staten Island, N. Y., and was educated in the public schools there. Previous to his connection with Air Reduction, he was in the sales department of Holt & Co., flour merchants, and the Western Electric Company, which he represented in Chicago and Denver, Colo. He began his career with Air Reduction as a salesman in the New York metropolitan district in 1916. Later he was appointed manager of the Chicago district,



Edward M. Sexton

and from this position was transferred back to New York as manager of the metropolitan district. When in 1922 the Davis-Bournonville Company's personnel was merged with that of Air Reduction, he was selected to manage the railroad sales department at New York.

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SINEWS FOR SERVICE

If the service is tough — so are Moly irons and steels. Take slush pumps in the oil fields . . . driven continuously and operating under severe conditions.

Since no pump is better than its parts, many pump builders use Moly irons and steels for the vital parts . . . because they have proved their capacity to withstand the toughest going.

One manufacturer, for example, uses carburized Nickel-Moly (SAE 4615) for pump cylinders. It was selected primarily because it takes a case impervious to the abrasion of well cuttings; and pressure is always constant. Minimum distortion from heat-treating was also a factor. . . . Just one of many cases where Moly steel or iron has settled a difficult prob-

lem — to the mutual advantage of the manufacturer and the user of the product. From either standpoint, Moly steels and irons will prove well worth their investigation.

Our technical books, "Molybdenum in Steel" and "Molybdenum in Cast Iron," will be found of unusual interest to engineering and production heads in any industry using or producing ferrous products. A simple request brings either or both — and, if desired, puts your name on "The Moly Matrix" monthly mailing list. Our experimental laboratory facilities are available for the study of any special problem in alloy steel or iron. Climax Molybdenum Company, 500 Fifth Avenue, New York City.

PRODUCERS OF FERRO-MOLYBDENUM, CALCIUM MOLYBDATE AND MOLYBDENUM TRIOXIDE

Climax Mo-lyb-den-um Company

Personal Mention

General

A. C. MELANSON, who has been appointed superintendent of motive power and car equipment of the Quebec district of the Canadian National, with headquarters at Quebec, Que., as noted in the February issue of the *Railway Mechanical Engineer*



A. C. Melanson

entered railway service in April, 1911, at Moncton, N. B., as a machinist apprentice. Subsequently he was appointed tracer and then draftsman. In May, 1919, he was transferred in the latter capacity to Toronto, Ont., and in January, 1922, became material inspector. He was transferred as material inspector to Montreal, Que., in July of the following year and a year later to Stratford, Ont. In April, 1924, he was appointed superintendent of the St. Malo shops at Quebec.

GEORGE S. WEST, superintendent of the Pittsburgh division of the Pennsylvania, has been appointed general superintendent of the Southwestern division, with headquarters at Indianapolis, Ind. Mr. West was born at Altoona, Pa., on June 23, 1893, and was graduated from Pennsylvania State College in 1917, with the degree of Bachelor of Science, Railroad Mechanical Engineering. He entered the service of the Pennsylvania on June 14, 1909, as a laborer on the Buffalo division, working in this capacity during the summers of 1909, 1910 and 1911. After entering the service permanently in 1912, he served successively as helper, car repairman, blacksmith helper, draftsman, and

machinist, and on April 16, 1920, he became motive-power inspector. On November 1 of the same year he was appointed assistant road foreman of engines at Philadelphia and on February 15, 1923, became assistant master mechanic at New York. On November 1 of that year he was appointed assistant engineer of motive power of the Central Pennsylvania division and on June 16, 1929, became master mechanic at Buffalo, being transferred



George S. West

to the Philadelphia Terminal division on March 1, 1930. Mr. West was appointed superintendent of the Monongahela division on November 1, 1931; superintendent of the Erie and Ashtabula division on September 16, 1932; superintendent of the Maryland division on July 1, 1933, and superintendent of the Pittsburgh division on April 1, 1935.

Master Mechanics and Road Foremen

D. M. SMITH, division master of the Canadian Pacific at Edmonton, Alta., has been transferred to Winnipeg, Man., to succeed G. Moth, division master mechanic at that point, who has retired.

J. W. MCKINNON, division master mechanic of the Canadian Pacific at Calgary, Alta., has been transferred to Edmonton, Alta., to succeed D. M. Smith as division master mechanic at that point.

W. D. DICKIE, general foreman, motive power and car department, of the Canadian Pacific, at Moose Jaw, Sask.

* * *

has been appointed division master mechanic, with headquarters at Calgary, Alta., to succeed J. W. McKinnon.

Car Department

W. A. HOLCOMB, gang leader in the car department of the Norfolk & Western at Bluefield, W. Va., has become gang foreman, succeeding Frank Spencer, deceased.

Shop and Enginehouse

J. H. EVANS, a blacksmith in the shops of the Norfolk & Western at Roanoke, Va., has become assistant foreman, succeeding C. E. Pond.

H. J. SAUTER, assistant foreman in the machine shop of the Norfolk & Western at Portsmouth, Ohio, has become assistant machine-shop foreman, succeeding J. G. Smith.

J. G. SMITH, assistant machine-shop foreman of the Norfolk & Western at Portsmouth, Ohio, has been promoted to the position of machine-shop foreman, succeeding J. H. Hahn.

J. H. HAHN, machine-shop foreman of the Norfolk & Western at Portsmouth, Ohio, has become back-shop foreman at Portsmouth, succeeding E. C. Goetz, deceased.

C. E. POND, assistant foreman at the Roanoke, Va., shops of the Norfolk & Western, has become assistant blacksmith shop foreman, succeeding W. H. Noell, retired.

G. S. DEARMOND, a machinist in the shops of the Norfolk & Western at Portsmouth, Ohio, has become assistant foreman in the machine shop, succeeding H. J. Sauter.

Purchasing and Stores

C. F. MCNEAL, local storekeeper of the Northern Pacific at Auburn, Wash., has been appointed division storekeeper at Glendive, Mont., to succeed R. G. Becker.

R. G. BECKER, division storekeeper of the Northern Pacific at Glendive, Mont., has been appointed district storekeeper at the Como store, St. Paul, Minn., to succeed A. C. Johnson.

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The yard and shops of the Norfolk & Western at Portsmouth, Ohio, when the Ohio River was at the 68-ft. stage—it later rose to about 75 ft.

T-Z Car Specialties

Type 4 clamp for hopper car side application.



Air brake retaining valve bracket.



Type 3 clamp for box and other types of cars.



T-Z Pipe Clamps

The long bearing surface prevents breakage and pipe wear as well as longitudinal movement and pipe vibration. The firmly clamped piping prevents connection failures which minimizes leaking air lines resulting in more efficient operation of the air brake system.

The clamps eliminate the use of angle irons, U bolts and nuts, and are economically applied and maintained. They are efficient and inexpensive.

T-Z Patented Safety Tread Brake Step

Raised and depressed nibs produced by a modern method of punching the tread provides a special drainage feature and assures secure footing in any direction under all weather conditions. No metal is cut away which makes the T-Z tread much stronger than the ordinary steel brake step.

The steps are made, as requested, from No. 10 U. S. S. gage open-hearth or copper-bearing steel. They can be applied to all types of freight cars in accordance to A.A.R. specifications.

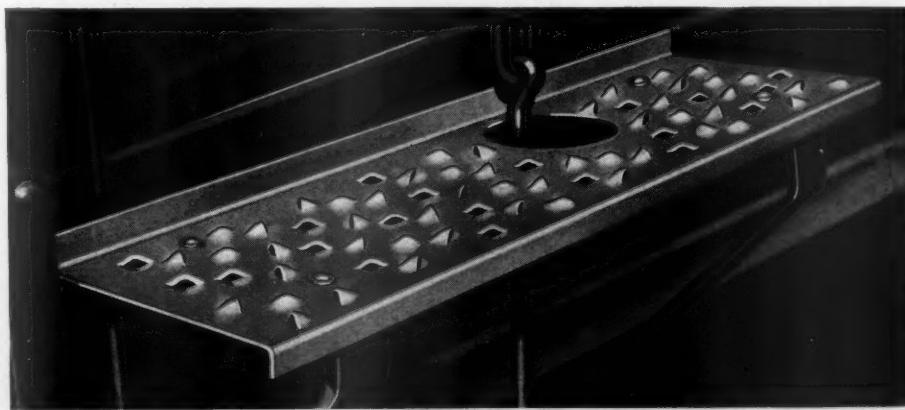
Retaining Valve Bracket

It can be permanently attached to any type of car end with either rivets or bolts. The retaining valve may be applied or removed from the outside of the car.

The slots eliminate the necessity for accuracy in cutting to length the connecting pipe.

It is a time and money saver should any trouble occur with either the retaining valve or pipe leading to it.

T-Z brake step applied to a car.



T.Z. RAILWAY EQUIPMENT CO., Inc.

310 S. MICHIGAN AVENUE

CHICAGO, ILL.

DAVID MCK. FORD, assistant to the vice-president, purchases and stores, Canadian National, has been appointed general purchasing agent for the system. Mr. Ford was born in Glasgow, Scotland, and first entered railway service with the North British Railway in 1900 as a clerk in the general goods manager's office. Three years later he became associated with the Caledonian Railway as a clerk in the district superintendent's office. In April, 1905, he went to Canada and entered the employ of the Canadian Northern at Toronto, as a clerk, but in July of the same year he left to accept a position as chief clerk in the operating and accounting department of the Halifax & Yarmouth at Yarmouth, N. S. In December, 1905, he went to the Halifax & South Western as chief clerk

in the auditing and accounting department, with headquarters at Bridgewater, N. S. In July, 1910, he returned to the Canadian Northern Express Company as auditor and cashier at Quebec and in February, 1916, was appointed auditor, Quebec lines of the Canadian Northern. Mr. Ford was appointed accountant, eastern lands department of the Canadian National, in September, 1916, and in November, 1918, became chief clerk in the president's office, C. N. R. and Canadian Government Merchant Marine, which position he held until 1922, when he was appointed office assistant to the president. Upon the formation of the present Canadian National in 1923, Mr. Ford became assistant to the director of purchases and supplies and in 1924 assistant to vice-president of purchases and stores.

GISHOLT STANDARD TOOLS.—The Gisholt Machine Co., Madison, Wis., illustrates an extensive line of standard tools and holding devices in its 38-page catalog. These tools are adapted to a wide range of work on No. 3, 4 and 5 ram type universal turret lathes and on other types of Gisholt turret lathes.

CONTOUR SAWING.—A treatise on a process of metal cutting, known as Contour Sawing, has been issued by Continental Machine Specialties, 1301 Washington avenue, South, Minneapolis, Minn. The book gives a history of band sawing and band filing and discusses the saws and operating technique for this field.

GRILLES AND REGISTERS.—Catalog 37T of the Hart & Cooley Manufacturing Co., 61 W. Kinzie street, Chicago, is devoted to a line of H & C grilles and registers developed especially for use in the air conditioning of railroad equipment. All drawings are listed in numerical sequence, with a footnote at the bottom of each giving information regarding the application of the item.

THE SUPERHEATER.—A series of discussions on the superheater as a factor in locomotive design is being issued by The Superheater Company, 60 East Forty-Second street, New York, in the form of a bulletin entitled "More Power to You." The bulletin consists of a series of Railway Age advertisements which briefly present the advantages of high superheated steam temperatures.

WELDING WIRE AND EQUIPMENT.—An attractive loose-leaf binder, issued by the Hollup Corporation, Chicago, describes Flexarc welding machines, Hollup accessories, and various Sureweld coated rods used for welding operations in general industry, as well as by the railroads in the construction of light-weight streamline cars, welded hopper cars, etc. The latest specifications of the American Welding Society as regards materials and physical tests are quoted, also S.A.E. specifications for various types of steels.

Trade Publications

Copies of trade publications described in the column can be obtained by writing to the manufacturers. State the name and number of the bulletin or catalog desired, when mentioned in the description.

INDUSTRIAL PACKINGS.—The United States Rubber Products, Inc., 1790 Broadway, New York, has issued a 112-page manual on the subject of industrial packings for use by engineers and executives in the railway, automotive, marine and aviation fields.

WELDING.—"The Welding of Wrought Iron" is the title of the service bulletin issued by the A. M. Byers Company, Pittsburgh, Pa.

RIVETING ALUMINUM.—The Aluminum Company of America, Pittsburgh, Pa., has issued a revised copy of its booklet on The Riveting of Aluminum and Its Alloys. The booklet contains 36 pages.

METALAYER.—"Railroad uses for Metalayer" is the subject of the pocket size, six-page folder No. 1207 issued by the Metals Coating Company of America, 495 North Third street, Philadelphia, Pa.

PROTECTIVE COATING.—The Dampney Company of America, 1243 River Road, Hyde Park, Boston, Mass., has revised its eight-page bulletin describing a protective coating for locomotive, steamship and stationary boilers.

BOLT HEADING AND FORGING MACHINES.—Bulletin 64 of the Ajax Manufacturing Company, Cleveland, Ohio, is devoted to an illustrated description of Air-Clutch operated bolt-heading and forging machines and their construction.

METAL PAINT.—"Koppax, Black Paint," issued by the Koppers Products Company, Pittsburgh, Pa., contains instructions for the painting of metal surfaces of many kinds, including locomotive front ends and fireboxes and railroad bridges. Koppax is a water-resistant, heat-resistant and corrosion-resistant material.

PIPE REPAIR CLAMPS.—Under the title "Repair Clamps and Saddles for Steel and Cast-Iron Pipes" the M. B. Skinner Company, South Bend, Ind., has issued catalog No. 36 containing illustrations and information regarding the methods of repairing pipe-line leaks in shop, terminal or power-plant air lines, fuel lines, high-pressure steam lines, etc.

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Illinois Central Mikado-type locomotive at modern equipped enginehouse, Markham, Ill.